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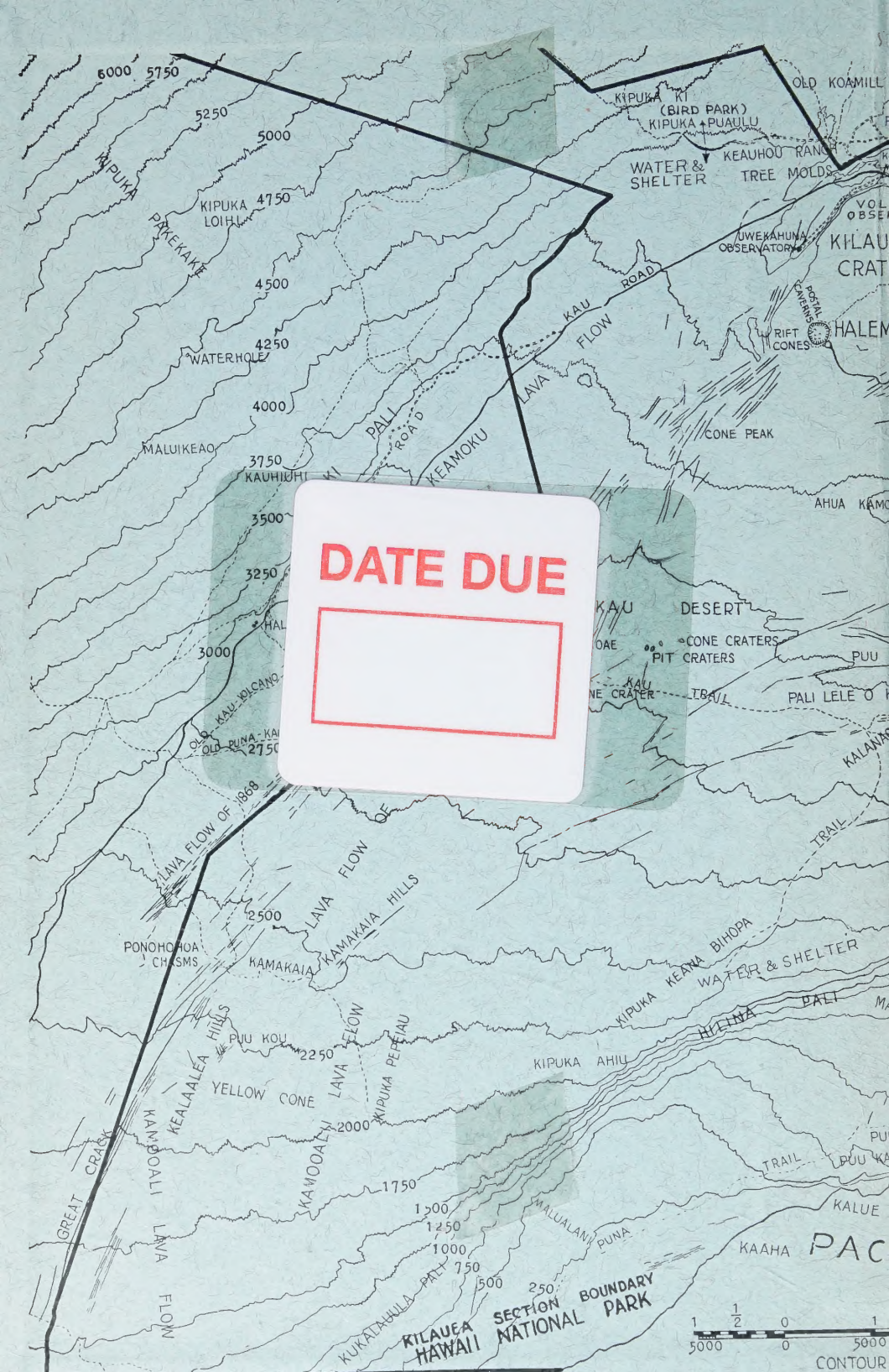
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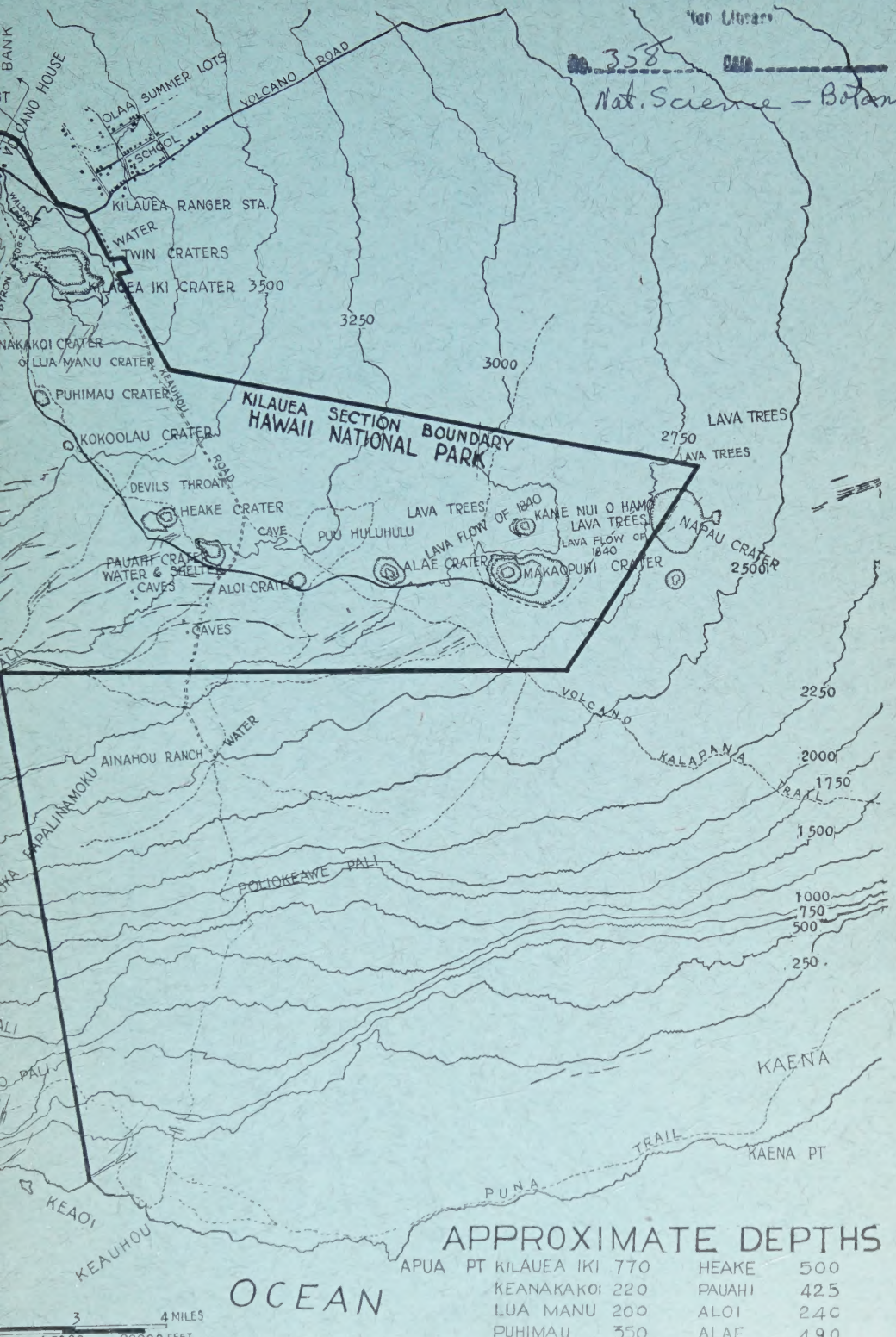
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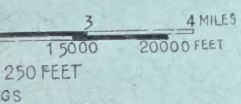
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	KOKOOLAU	100	MAKAOPUHI	1000
	DEVIL'S THROAT			250

OCEAN



To Roger W. Toll

A modest author asks
that I present this copy of the
first work in direct reference to
Hawaii National Park

Leo J. Allen /

Presented to ↓

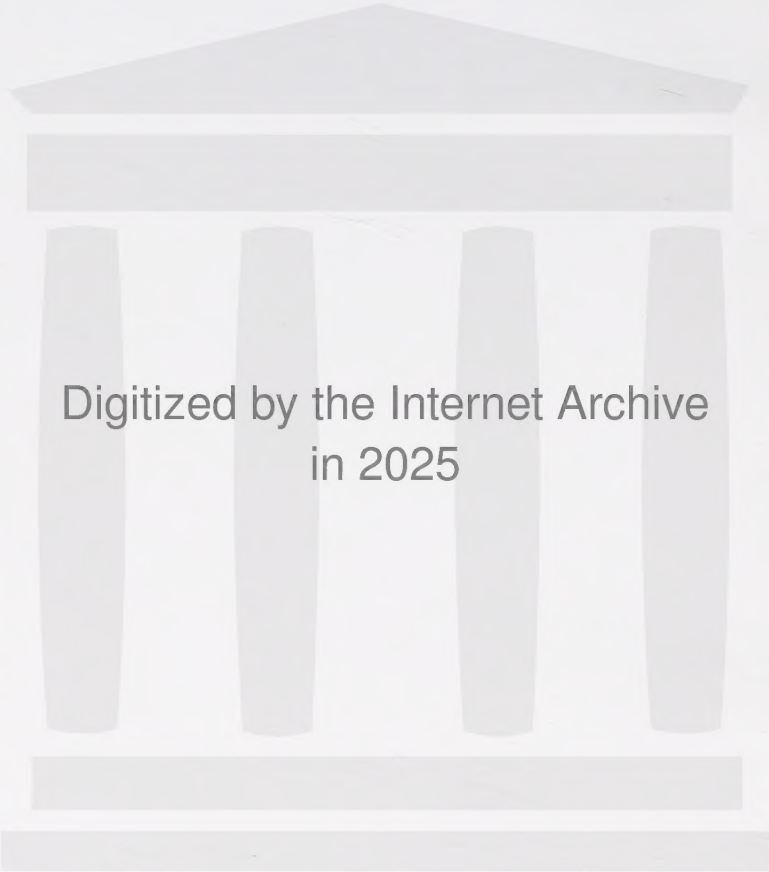
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KILAUEA VOL

Exemplifying the method by which



AT NIGHT

Maian Islands arose from the sea

From the painting by C. W. Best

Illustrated Guide to the More Common
or Noteworthy

Ferns *and* Flowering Plants of Hawaii National Park

With Descriptions of Ancient Hawaiian Customs and
an Introduction to the Geologic History
of the Islands

By OTTO DEGENER, B. S., M. S.
Botanist at University of Hawaii, 1925-27
Naturalist at Hawaii National Park, 1929

[illegible]

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Otto Degener

THE COLORADO MOUNTAIN CLUB

IN COLORADO

1911-1929

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(Usually pronounced as in German or Spanish.)

Scientific names in *italics*.

Other words in ordinary type.

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PURPOSE AND SCOPE

This book is intended to meet the needs of visitors to Hawaii National Park who have had little or no formal botanical training, yet who wish to know the most interesting facts about local ferns and flowering plants, particularly in relationship to ancient Hawaiian customs. It includes not only the more common or noteworthy plants found within the confines of the Kilauea and the Haleakala Sections of the Park but also those that may attract the attention of the visitor motoring to or from their boundaries. The contents of this book are based largely on direct observations made by the writer in the field, supplemented by published and unpublished accounts of others which have come to his attention while working on his *Flora Hawaiiensis* (p. 313) or New Illustrated Flora of the Hawaiian Islands, begun in 1922.

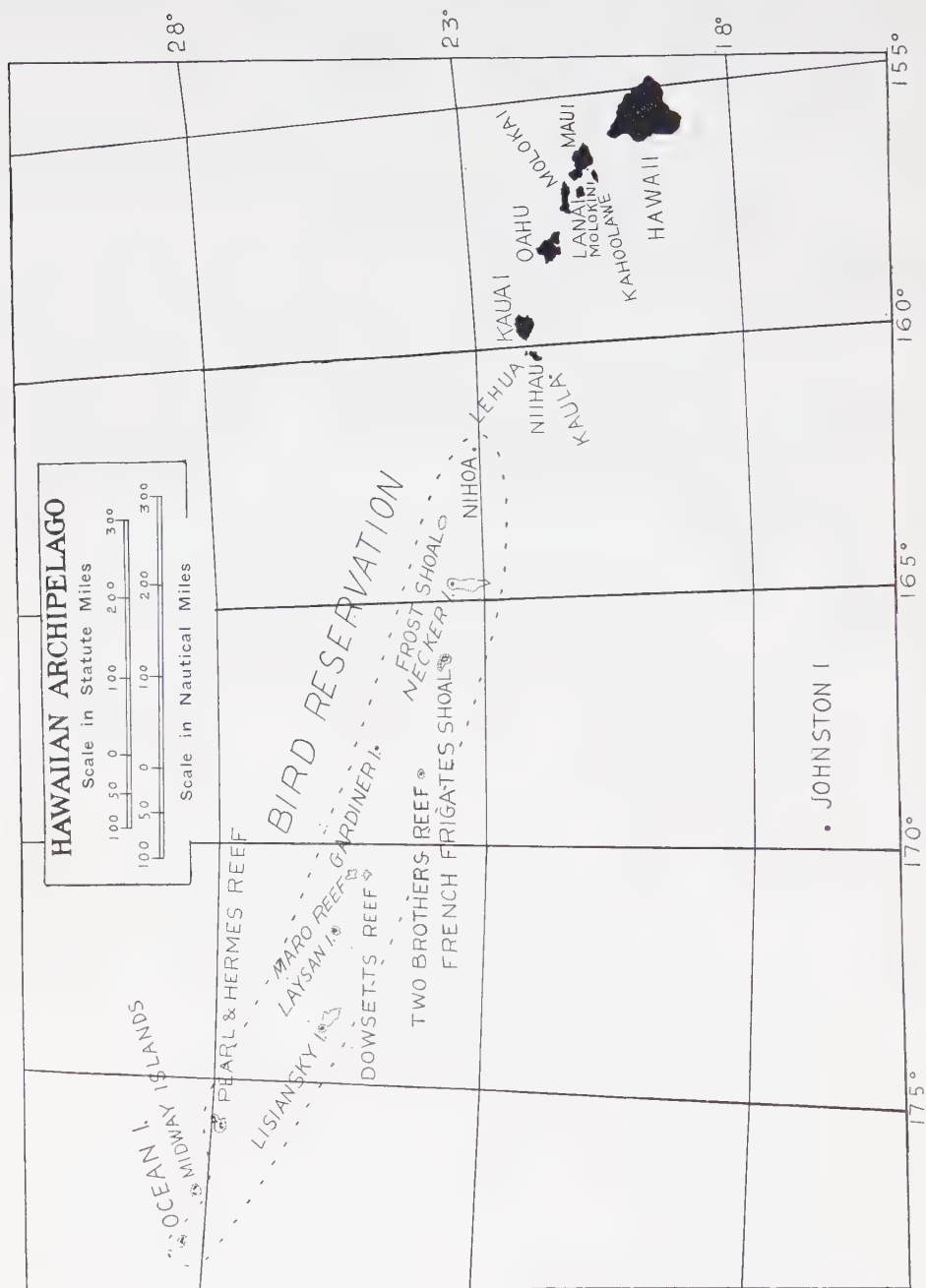


FIGURE 1—Hawaiian Archipelago.

GEOLOGIC HISTORY OF THE HAWAIIAN ISLANDS

The remarkable character of the Hawaiian flora is so dependent on the geologic history of the Islands that a brief outline of it is appropriate here.

Hundreds of millions of years ago, a rift or crack, no doubt with various branches, developed in the ocean floor in the mid-Pacific about 2,400 miles east of Japan and gradually extended south-eastward for almost 2,000 miles. From various points on the rift lava gushed out occasionally, thus slowly building up a series of volcanic mountains. Possibly by the time of the Cretaceous Period, variously estimated by geologists as ninety to one hundred twenty million years ago, some of these mountains attained so great a height that their summits rose above the surface of the sea to form islands of considerable size. In general the most westerly ones arising from this volcanic rift, such as Ocean Island, were the first to lose volcanic activity. Those farther south-east, with exceptions perhaps, lost their volcanic fires successively later, while the last island of the entire series, the Island of Hawaii, is the only one possessing volcanoes that are still conspicuously active. A general account of the present condition of the islands along this rift is interesting (Fig. 1).

The most westerly islands mentioned above exist today as dangerous reefs and shoals, as stretches of wind-blown sand or as almost barren rocks where sea-birds nest at certain seasons. Some are actually coral atolls raised but a few feet above sea level on a submerged volcanic base, while others are volcanic coneremnants several hundred feet in height. Their small size in comparison to most of the islands to the east of them, which we know as the Hawaiian Islands proper, is thought to be due to two or possibly even three causes. First, they have long ceased to grow by the outflow of fresh lava. Second, they are so old that in many cases the rains, winds and waves have had time to erode much of their igneous rocks away. Third, they may have slowly subsided.

The Island of Kauai is east of these extensively eroded bird islands. Though the greater part of its mass may be as old as the latter islands, Kauai is partly covered with a veneer of lava of more recent age. Nevertheless, even this comparatively thin layer is so old that the rain of the high mountains, continually collecting in streams and charged with silt, sand and boulders, has been able to cut huge, scenic canyons through this veneer deep into the

island's sides. Of these canyons, the best known and most easily accessible are Olokele and Waimea (Fig. 2). Then apparently long after this major period of volcanic activity, the very last outburst of volcanism on Kauai produced Kilohana Crater, near the town of Lihue.



(Photo by W. J. Senda)

FIGURE 2.—Waimea Canyon, Island of Kauai; *kukui* trees in valley.

Oahu, the island east of Kauai, is composed of two distinct volcanic areas. The western, centering around the Waianae Range, may be more or less contemporaneous with Kauai. The eastern part, which is composed mainly of the Koolau Range, had its last great eruptive activity later. Its lava flows therefore overlap the ends of those extending from the Waianae Range. Similarly as Kilohana Crater completed the eruptive stage of the Island of Kauai, so Diamond Head (Fig. 3), Punchbowl and a number of less well-known craters of south-eastern Oahu completed the eruptive phase of that island. This fact becomes evident to every visitor who sails into Honolulu harbor and sees these well-preserved craters before him.

Molokai is similarly composed of two volcanic masses. The western range is nowhere more than 1,400 feet high and conse-

gently extremely arid. The eastern and larger range, on the other hand, rises to a height of about 5,000 feet, thus causing the trade winds to precipitate their moisture and making it possible for a dense rain forest to cover its upper slopes. Whether the last great volcanic activity in this island preceded or followed that of Oahu is not known with certainty.



(Photo by 11th Photo Section, U. S. Army, Air Corps)

FIGURE 3.—Diamond Head, one of the last craters formed on the Island of Oahu.

There is rather conclusive evidence that the western end of the Island of Maui is composed of long-extinct volcanic mountains that are much eroded, Mt. Eke remaining the hard core of one of them. The eastern base of these worn mountains was later covered by the flows from the huge Crater of Haleakala (Fig. 4). Though this crater is now apparently extinct, we have two proofs of its activity within relatively recent times. First, its cinder cones are still well preserved. Second, a stone wall built by the Hawaiians on its flanks in prehistoric times has been partly destroyed by a lava flow. Moreover, one of the early white settlers was told by a native informant that this flow occurred the year his grandfather was just old enough to carry a coconut. By estimating the probable date of birth for his informer and that of the father and grandfather, the settler concluded that the last lava flow must have occurred about the year 1750.

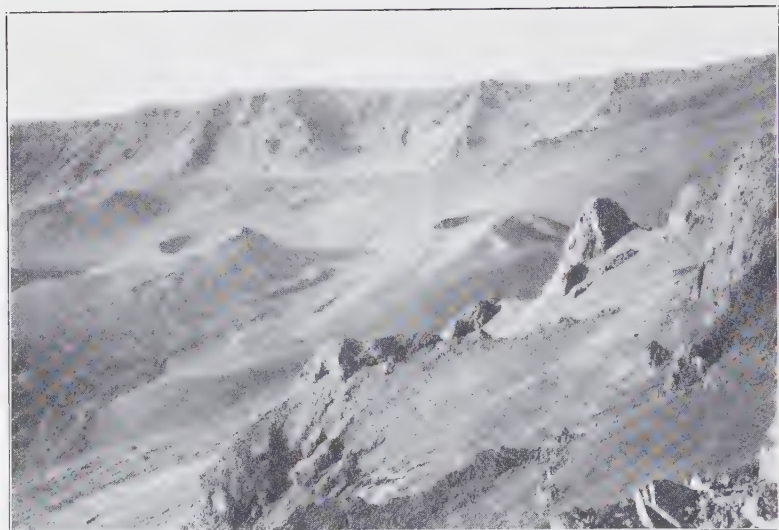


FIGURE 4.—Haleakala Crater as seen from the Rest House.

The Island of Hawaii (Fig. 5) is the last island of the series on this rift. It apparently was built by the combined action of five distinct volcanic centers that can be recognized today as Kohala Mountain, Mauna Kea, Hualalai, Mauna Loa and Kilauea. The north-western center, now comprising the District of Kohala, was undoubtedly the first to become extinct if not the first to be formed. It therefore gave the forces of erosion uninterrupted opportunity to wear canyons into its sides. The rest of the island, on the contrary, is little eroded. This is due to the fact that the four remaining volcanoes broke through the older land and covered it almost completely with their lava flows. Of these little-eroded volcanoes, Mauna Kea seems to be practically of contemporary age with Haleakala so far as most of its surface lavas are concerned. Hualalai was still more recently active than these, having produced a lava flow as late as 1801. Mauna Loa and Kilauea, the two volcanoes at the extreme end of the rift, are more or less active to the present day. In 1790 and again in 1924 Kilauea erupted explosively as Figure 8 of its vent, termed Halemaumau, shows. Usually, however, its activity is relatively quiet. Views of Halemaumau during one of these phases are shown. Figure 6 is from a photograph of Halemaumau taken at six o'clock in the afternoon of July 25, 1929, while



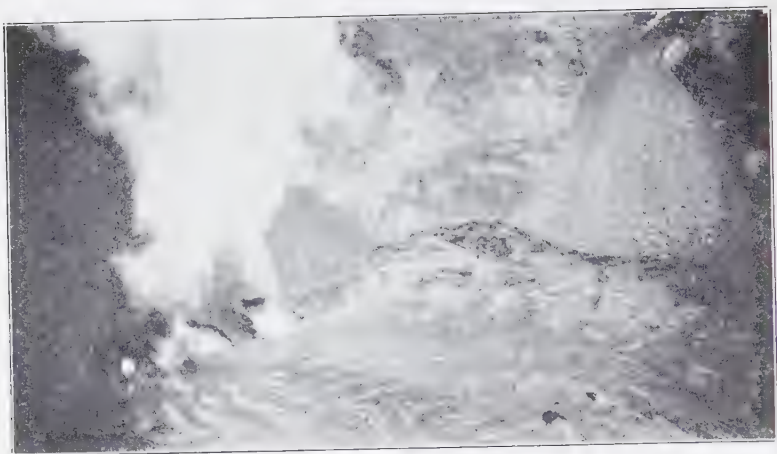
(Courtesy W. F. Pope)

FIGURE 5.—Map of Island of Hawaii showing more recent lava flows.

the following figure (Fig. 7) shows the same view taken two hours later when night had fallen.

ORIGIN OF THE HAWAIIAN FLORA

The plants that existed on the earth one hundred million years or so ago differed from those that exist today. They were in general more primitive, not yet having had sufficient time to



(Courtesy J. K. Higashida)

FIGURE 6—Halemaumau in action at 6:00 P. M., July 25, 1929.



(Courtesy J. K. Higashida)

FIGURE 7—Halemaumau in action at 8:00 P. M., July 25, 1929.

evolve to their present state. Probably about that time the chain of islands of which the Hawaiian group is a part gradually arose from the sea, a mass of bare lava. It is interesting to speculate how these barren islands became clothed with vegetation.

Mosses and ferns produce spores or unicellular reproductive bodies of microscopic size that, like dust, can be borne for great distances by the wind. Orchids (p. 118) produce minute seeds



FIGURE 8—Explosive eruption of Halemaumau in 1924.

that are extremely light. Plants like the *railliardia* (p. 302) bear spreading hairs on their small fruits to act as parachutes that enable them to be carried more readily by the wind. Such plants may have reached these islands during windstorms.

The *hala* (p. 47), *noni* (p. 282), *naupaka* (p. 292) and others either have corky material around their fruits or seeds, or air spaces within them. This enables them to float in sea water for months or even years. They, no doubt, were carried here by ocean currents.

The *peperomia* (p. 124) and mistletoe (p. 150) have sticky,

seed-like fruits. The strange sedge *uncinia* (p. 68) and several of the native beggar-ticks or *kookoolau* (p. 294) bear hooks or barbed hairs on their dry fruits. It seems reasonable to think that these plants reached this chain of islands attached to driftwood or more likely to the bodies of flying birds blown off their courses during storms.

Very many plants like the raspberry (p. 170) and the native lobelia relatives (*Clermontia*, p. 286, *Cyanca*, *Rollandia*, *Delissea*) have adopted a very efficient method for the distribution of their seeds and the establishment in the soil of the seedlings arising from them. Their seeds are indigestible but are contained within edible and often conspicuous fruits that tempt some bird or other animal to eat them. Thus birds frequently carry them in their alimentary tracts for considerable distances and at length deposit them in their droppings on the ground. Seedlings developed from seeds carried in this way have the unique advantage of beginning their growth in fertilized, or manured, soil.

On our chain of volcanic islands the conditions as to soil, climate, competition with plants and animals, and isolation by mountain ranges or bodies of water were obviously not identical with those elsewhere. Consequently almost every plant immigrant that found refuge here hundreds of thousands of years ago either became locally extinct or gave rise to a race of offspring that gradually evolved along a different line from its relatives left behind on the continents or on the islands to the south. In general the longer the race has lived in the Hawaiian Islands, the greater has been the opportunity for change. Therefore we notice that today the offspring of the earlier immigrants for the most part have become more modified from the ancestral condition than have those of later arrivals. The offspring of comparatively recent immigrants, on the other hand, have become little if at all modified. As a result we find that about 85 per cent of the present native Hawaiian flora consists of plants that have been so changed by local conditions from the ancestral structure that they are now recognized as being peculiar to these islands. Such plants are said to be "endemic," while the kinds found native in these islands that have not yet perceptibly changed from their relatives growing elsewhere are termed "indigenous." Plants brought here purposely or accidentally by the Polynesian and other races are said, in contrast, to be "introduced."

Due to the relatively weak competition among plants living in

isolation on the Hawaiian Islands, many of the archaic types formerly enjoying a more extended range have persisted here to the present time in a more or less modified form though exterminated elsewhere. Hence the endemic vegetation of these islands largely comprises a unique *flora relict*a, counting among its members strange arborescent plantains, composites, violets, geranium relatives, and other wonders of plant life.

After the discovery of the Islands by Captain Cook in 1778, the former balance of nature changed rapidly, working havoc with the endemic flora. Scores of plants that took hundreds of millions of years to evolve have been exterminated since that year of discovery, less than two centuries ago. Hundreds more are on the verge of extinction and the rest, for the most part, are doomed to the same fate in a comparatively short time. Two factors are responsible for this rapid decline of the endemic flora, namely, introduced animals and introduced plants.

Cattle were first brought here by Vancouver in 1793; sheep were first brought probably by Calmet and later by Vancouver in 1793; horses were first brought by R. J. Cleveland in 1803. As the number of these animals in the Islands gradually increased, the Hawaiian plants inhabiting the more fertile regions became more and more exposed to injury by trampling and browsing, and in most cases succumbed. Goats were introduced by Captain Cook. Their feral descendants soon roamed the drier and rockier regions in small herds, particularly on the Island of Hawaii, taking a heavy toll of the plants peculiar to these localities. Pigs, introduced by the Hawaiians in prehistoric times, continue their depredations in the wetter jungles to the present day.

The choicest lands were cleared of their native plants to give place to sugar cane, coffee, pineapple and other crop plants. Plants purposely introduced for food, such as the guava (p. 228), or as ornamentals, such as the lantana (p. 251) and the melastome (p. 226), escaped from cultivation. Still others came in ships' ballast, with fodder and merchandise, in impure garden seed and in countless other ways. Many of these vigorous plants accustomed to keen competition in their original homes on the continents found conditions for growth ideal in these islands. Many spread like wild-fire, crowding out the pampered native plants that stood in their way. Today the lowlands are almost destitute of Hawaiian vegetation, being covered with troublesome weeds that hail from almost every tropical and subtropical coun-

try in the world. It is only in the rain forests that the Hawaiian plants are still supreme. This is due to the fact that weeds inhabiting similar districts on the continents are rarely transported to these shores. As the number of plants introduced from all types of regions is, however, steadily increasing, the native rain forest flora will likewise eventually succumb.



(Courtesy T. J. Allen, Jr.)

FIGURE 9—Lava of *aa* type.

Just as about 85 per cent of the native plants of the Hawaiian Islands differ markedly from those growing elsewhere so, in a general way, does a smaller percentage of plants of one island of the Hawaiian group differ to a lesser degree from those growing on another island. In fact, it is not infrequent to find a definite kind of plant, which has no counterpart elsewhere, growing only on a single mountain, ridge, valley, or *kipuka* or oasis. This condition in the native flora is due to many complex and interrelated factors. Within a relatively small area these islands offer extremely diverse ecological conditions to land plants. They can find a foothold from sea level to an altitude of almost 14,000 feet, on Mauna Kea and Mauna Loa. They may have tropical heat throughout the year, as in the Kau District of the Island of Hawaii, or freezing temperatures for much of the time, as on the three highest mountains of these islands. They may grow under conditions of ex-

treme aridity, as in many localities on the leeward side of the islands, or of almost perpetual rainfall as on the summit of the Island of Kauai. Furthermore, they are offered opportunity to grow either in deep, mellow soils found in the valleys, or on rough *aa** (Fig. 9) or glassy *pahoehoe*** (Fig. 10) lava flows which cover vast areas on Hawaii and Maui; on salt-impregnated



FIGURE 10—Lava of *pahoehoe* type.

(Original)

soils, such as may be found south-east of Kilauea, that are actually poisonous to many plants; or on soils of great fertility. If a plant becomes isolated from its kind by being transported as seed or

* A *pahoehoe* flow is characterized, as the Hawaiian word signifies, by a velvety appearance. It is lava that has cooled when at rest or nearly so. It therefore resembles liquid lava in appearance. Tar oozing from a pavement on a hot day simulates *pahoehoe* on a small scale.

** The surface of an *aa* flow is characterized by jagged, angular and rough masses of lava, extremely variable in size and shape. The flow forms by congealing while yet in motion, the front and surface solidifying into a crust in the cool air and the remainder cooling probably due to infiltration of steam generated from the water in the soil below. As the crust becomes engulfed in the flowing mass, fresh liquid lava takes its place and likewise solidifies. As this continues the entire mass becomes a sluggishly advancing flow in which liquid lava is rarely seen. Solid lumps of lava from the upper part of the front of the stream tumble down its slope, advancing ahead of the lower part as this is retarded because of friction with the surface of the ground.

spore to a different geographical or ecological region on the same or on a different island, or even by being surrounded by extensive lava flows, it sooner or later begins to differ from its relatives. These differences may be actual, deep-seated and hence heritable from generation to generation in spite of external factors; or they may be merely apparent, superficially imposed by the environment on an impressionable organism and consequently exerting no influence on succeeding generations. Only in the case of the former are the resulting plants actually distinct from their relatives. In the latter case they are merely disguised representatives of the same kind.

When plants become hybridized to a greater or lesser degree with one or more relatives in the Islands, no doubt a comparatively frequent occurrence that usually escapes detection, a host of variable offspring may result. Some of these may become segregated, as previously mentioned, and give rise to yet other distinct kinds of plants which in turn may or may not hybridize. Such processes are doubtless largely responsible for the surprisingly large number of plants found in these islands that are apparently annectant, or intermediate, types between otherwise distinct kinds. This ability to hybridize has likewise, no doubt, been instrumental in the evolution of new kinds of plants locally. To distinguish between plants which (1) possess various degrees of actual differences which are transmissible by inheritance, (2) those that appear to be different from others but are actually the same, and (3) those that are more or less hybridized and do not as yet breed true but are still producing variable offspring, is a problem still demanding intensive and long-continued study.

REMARKS AND ACKNOWLEDGMENT

The plants described in the following pages are arranged, where possible, in the order of their complexity, the primitive in structure preceding those that are more advanced. For a book of this kind no key for identification is necessary, a perusal of the illustrations serving in its stead.

The writer is greatly indebted to his former student, Henry Wiebke, to Oliver Pohina and especially to Everett Brumaghin for knowledge of the native uses of plants; to Herbert Lau, to Yasuma Iwasaki and to others for executing the drawings; and to Herbert Gregory for stimulating him to devote his full time and resources to a study of the local flora. Without their aid and influence, this book might never have appeared. He also wishes



PLATE 1.—Upright *Psilotum* or Moa. (Original).

to express his appreciation to Thomas Allen, Superintendent of Hawaii National Park; to Mrs. T. A. Jaggard; to Harold S. Palmer; and to many other friends for helpful criticism.

PSILOTUM OR MOA

Two kinds of psilotum, the *moa* of the Hawaiians, may be found within the boundaries of the Park. Though rarely attaining one foot in length, both are unique plants because of their narrow, uniformly forking branches and inconspicuous leaves. In lieu of roots they have subterranean branches which are inhabited by strands of a microscopic fungus, or mold, called a mycorrhiza. This fungus in some way aids the plant in gaining part of its food.

The upright psilotum, *Psilotum nudum* (L.) Griseb., (Plate 1) of the botanist, is the more common of the two plants, growing on the ground or, rarely, on trees. It can be identified by its three-cornered stems and upright habit of growth. The flat-stemmed psilotum, *P. complanatum* Sw., (Plate 2), on the other hand, invariably grows on tree trunks, especially on those of the giant ferns. It has flattened stems that grow a short distance out from the trunk of the tree before drooping sharply like a mare's tail.

The two psilotums, which live throughout the tropics, and two plants called *Tmesipteris*, which live in Australia and New Caledonia, form a remarkable group termed *Psilotales*. They are neither ferns, clubmosses nor flowering plants but seem to resemble more closely certain primitive, long-extinct plants that are known only as fossils.

The leaves of psilotum are very small and scale-like. In the upper part of the plant they are deeply divided and bear three-chambered, yellow capsules called sporangia. When mature these split open to shed a cloud of dustlike reproductive bodies called spores. These spores germinate under favorable conditions into minute plants called gametophytes, or prothalli, which grow hidden entirely under ground, in the crevices of rocks or in the decaying trunks of trees. These were not known until around 1910 when a botanist took some spores and forced them into blocks of old pumice. After leaving these porous rocks in a moist place for about a year, he sliced them with a razor to reach the gametophyte for study. This, he discovered, is a minute, root-like structure which has a mycorrhiza living in its tissues. The latter aids it in gaining nourishment. At maturity the gametophyte produces microscopic



PLATE 2 Flat Stemmed Palmetto or Mea (Original)

sex organs called antheridia and archegonia. Within the antheridium numerous motile sperm develop, while within each archegonium rests a single egg. The sperm are finally liberated in wet weather and then actually swim to the archegonia to unite with the eggs. From such a union arises the next generation, called sporophyte, which consists of the plants here illustrated. Thus the large generation producing asexual reproductive bodies, called spores, gives rise to the minute generation producing egg and sperm. Such an alternation of unlike generations occurs in all the plants described in this guide. In the flowering plants, however, the gametophyte generation has become so obscured that only the botanist can recognize it.

The upright psilotum furnished the Hawaiians with two medicines. The tea, derived by boiling the plant, was given to babies suffering from the common disease called *ea* in Hawaiian and "thrush" in English. This is caused by a fungus (*Oidium albicans* Robin) that produces white patches in the mouth or on the tongue, and finally covers the entire mucous membrane with an even, white coating. The tea was also drunk as a laxative or cathartic. The oily spores, on the other hand, were given to infants as a remedy for diarrhoea, and were also used like talcum powder to prevent chafing which occasionally occurred from wearing the *malo* (p. 140), or loin cloth.

The upright psilotum was used in playing the Hawaiian game of "fighting cocks." Two players each took a branch of the plant and removed all but a single side twig. Then, holding the branch by the tip, this inverted twig acted as a hook. The two contestants locked hooks and slowly pulled until either the one or the other branch should break. The owner of the branch that remained intact thereupon declared his victory by crowing like a rooster.

CLUBMOSES OR WAWAEIOLE

Several kinds of clubmosses, the *wawaeiole* of the natives, grow in Hawaii National Park. These plants belong to the *Lycopodiales*, a group that may be considered somewhat equivalent to the *Psilotales* (p. 18) and the ferns in evolutionary development, though by no means closely related to them.

The nodding clubmoss (Plate 3), botanically known as *Lycopodium cernuum* L., is the most common representative of this group of plants in the Islands. It is found in the Kilauea Section of the Park in great numbers, forming dense thickets in the more



PLATE 3.—Nodding Clubmoss or Wawaiole. (Original). Habit, young strobilus, leaf, strobilus shedding spores.

open woods with the *uluhe* (p. 24) fern. It creeps along the ground for long distances, giving off at definite intervals stems one to three or more feet high. These, in turn, bear short, forking branches. The entire plant, with the exception of the root, is beset with innumerable awl-shaped leaves.

At maturity the smallest branches of the nodding clubmoss produce drooping, cone-shaped structures called strobili. As these ripen, the scale-like leaves turn back to expose axillary capsules, or sporangia. The sporangia, as in *psilotum*, liberate unicellular reproductive bodies known as spores. Upon germinating these grow into minute sexual plants, or gametophytes, containing male and female reproductive organs. Upon the fertilization of an egg borne in the latter, a new generation of clubmoss arises similar to its sexless grandparent and very dissimilar to its parents.

The spores of all clubmosses germinate so rarely that the gametophytes, or sexual generations, of most kinds are still unknown. In 1848 Spring, the specialist on this entire group of plants, wrote that as he had never seen clubmosses produce seed, he suspected that all the female plants had been exterminated in the Deluge and that only the males had survived, these growing to the present day. He obviously mistook the clubmosses, with their asexual spores, for flowering plants bearing highly specialized "unisexual" flowers that produce pollen grains only and no ovules to mature into seed. The mystery as to the life history of this strange group of plants was finally solved by Treub in 1886 in Java with the discovery of the sexual stage of the nodding clubmoss. In recent years the sexual generation of this same plant was discovered in New Zealand, and in 1922 the third find was made at Kilauea. Here the greatest number of gametophytes of any kind of clubmoss were gathered. These gametophytes, strange to say, grew by the thousands almost exclusively in the volcanically heated crevices of the Sulphur Bank and its vicinity.* The rarity of the gametophyte under normal conditions and its phenomenal occurrence in fumaroles is due to the fact that the ideal environment for the growth of the one generation is harmful to that of the other. Such an explanation may, in part, account for the extinction of most of the clubmoss relatives which flourished during the Carboniferous Period and largely built up our coal deposits with their branches, leaves and inflammable spores.

* Degener, O., *The Nodding Clubmoss; Popular and Technical Account of an Interesting Plant of Hawaii*, 1931. Pamphlet based on Bot. Gaz. 80:26-47. 1925.

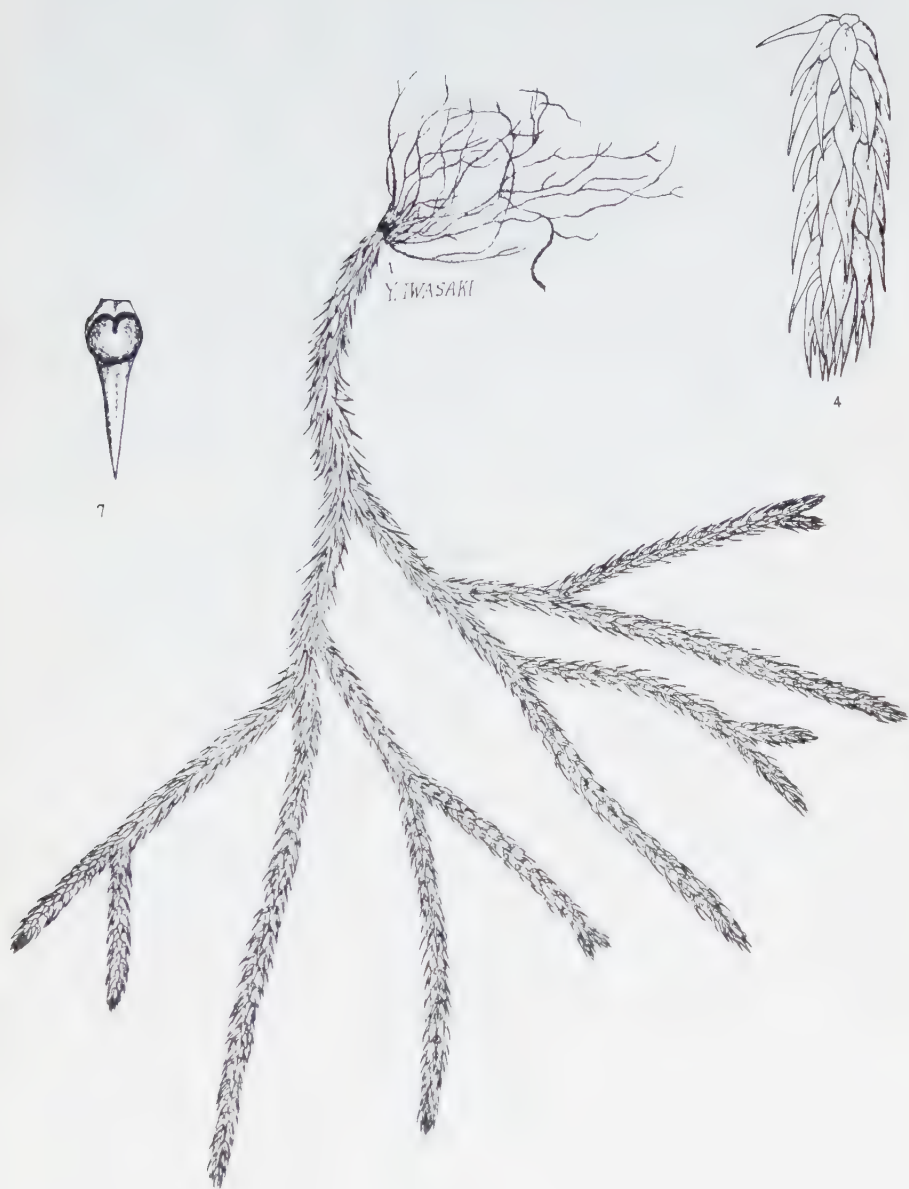


PLATE 4.—*Lycopodium polytrichoides* or Wawaciale. (Original)
Leaf showing spore-filled sporangium, habit, strobilus

Another clubmoss, which may be found east of Kilauea and in the Koolau Gap of Haleakala, is *Lycopodium venustulum* Gaud., a close relative of the continental *L. clavatum* L. This plant also creeps over the ground but, instead of producing nodding strobili, these structures are erect and exposed on a stalk. The plant is rather rare.

A few other clubmosses may, perhaps, be noticed by the visitor. For instance, *L. polytrichoides* Kaulf., and *L. phyllanthum* Hook. & Arn., grow along the trail between Makaopuhi and Napau Craters in the Kilauea Section. It is, however, useless to search on the ground for these rare plants as they grow on the moss-covered trunks of trees. *L. polytrichoides*, the smaller of the two, is shown on Plate 4. *L. phyllanthum* is two to six times as large and bears flattened leaves.

The Hawaiians used the nodding clubmoss, or *wawaeiole*, as a medicine for rheumatism. The patient bathed in cooled water in which the plants had been boiled for about three hours.

FALSE STAGHORN FERN OR ULUHE

At least four kinds of false staghorn fern, the *uluhe* of the Hawaiians, grow in these islands. The particular one botanically known as *Dicranopteris emarginata* (Brack.) W. J. Robinson (Plate 5) is native to the Islands of Hawaii and Oahu. It is especially abundant in the Kilauea Section of the National Park.

The *uluhe* ferns belong to a tropical family called *Gleicheniaceae*. Many of these plants have long, wiry, creeping stems which give rise at intervals to upright fronds. These differ from the fronds of other ferns in possessing numerous dormant buds. When the plants grow in rather open country these buds seldom develop further, and hence the fronds rarely exceed a height of two or three feet. But in localities where shrubs and trees tend to shade the plants, these buds quickly awaken into growth to produce complicated frond systems that clamber over the obstruction to a height of ten or even fifteen feet.

In spite of the unusual structure of the fronds, the *uluhe* is one of the most primitive ferns in the Hawaiian Islands. This is at once apparent by inspecting the under side of some of the older fronds. Here one may often see small dots, termed sori, scattered with some irregularity. Each is composed of about a dozen spherical, stalked bodies, called sporangia, that only the keenest eye can discern. In the more highly evolved ferns, the sporangia are not

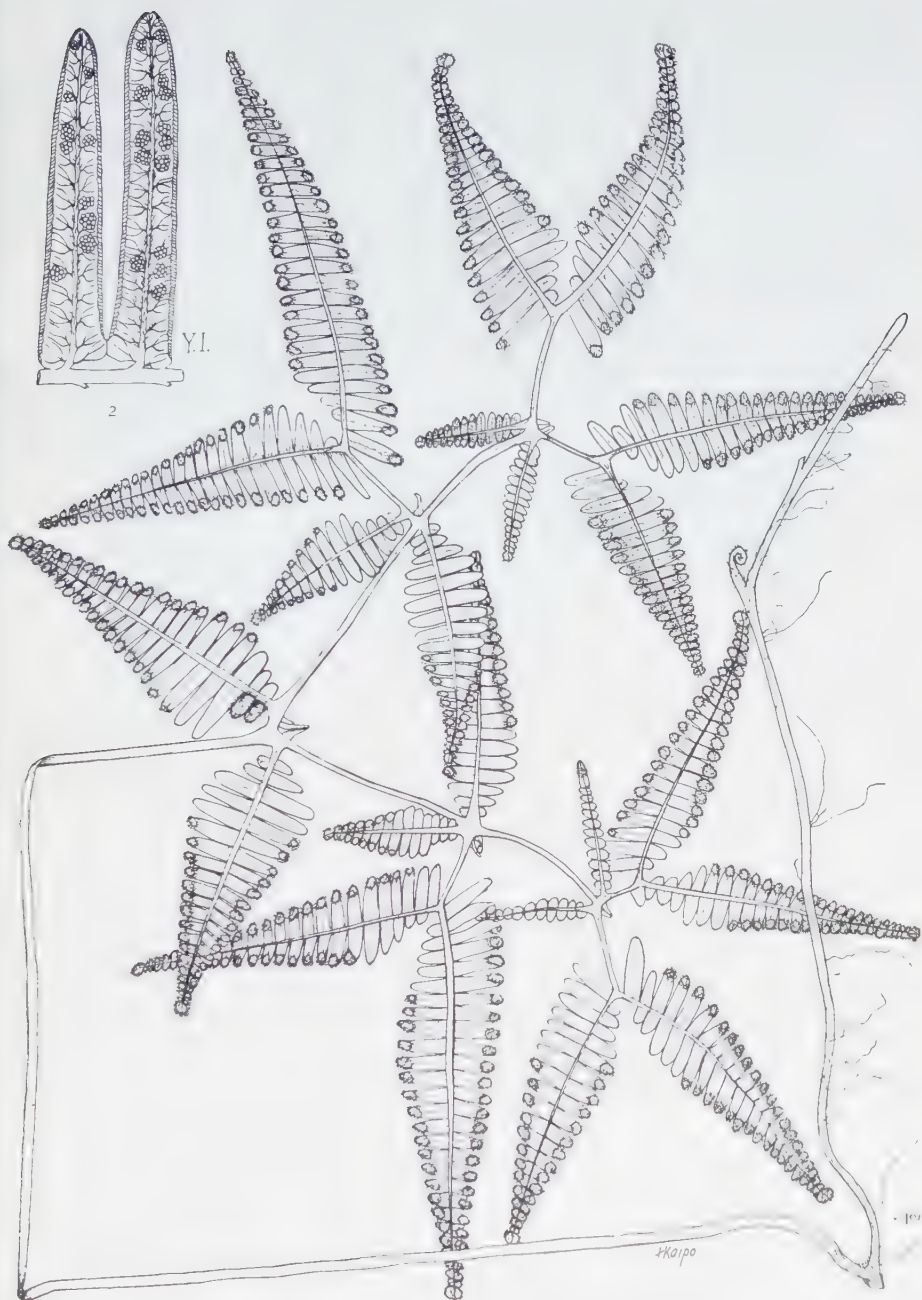


PLATE 5.—False Staghorn Fern or Uluhe. (Original).
Enlargement showing two segments bearing sori consisting of spore-filled sporangia

openly exposed to danger in this way but, instead, are protected by an outgrowth from the margin of the frond, as in the tree fern (Plate 6) and maidenhair, or are protected in some other way.

The sporangia of the *uluhe* fern, as well as those of nearly all other ferns, enclose numerous microscopic spores which are finally shed into the air as a fine cloud of yellow dust. Spores that fall in some moist locality may germinate and develop into small, green, often heart-shaped, sheets of cells called gametophytes, or prothalli, each a fraction of an inch in length. These finally produce sperm and eggs. From their union the asexual spore-producing generation that we commonly recognize as a fern then arises.

The *uluhe* ferns are almost the only native plants that are actually troublesome to man. Their thickets may be so dense as to be virtually impenetrable. Seeds of forest trees falling into such dark, tangled masses of living and dead fern fronds may germinate, but the growing seedlings usually die before being able to force their way into the light. When such thickets become dry during periods of drought, a carelessly discarded cigaret or a neglected camp fire may ignite them and thus cause a devastating forest fire. Even shrubs and trees of medium size are not immune from their attack. If they stand in the way of a spreading *uluhe* patch, they may be covered by the climbing fronds and weakened or even killed.

It is extremely difficult to eradicate the *uluhe*. Where the fern is found in small patches, it can be controlled after the first general clearing of the ground only by the continual digging up of the growing, brittle rootstocks that have managed to remain in the soil. Where the plants cover extensive forest areas, they may be exterminated by planting introduced kinds of bamboo in artificial clearings made in their midst. These giant grasses soon produce subterranean branches that spread in all directions whether *uluhe* grows over them or not. From these branches, sharp shoots soon arise which, instead of spreading, press straight up through all obstacles before producing a dense crowd of blades, or leaves. Thus, in time, a forest of bamboo spreads over the tangle of fern and kills it with its dense shade. When that has occurred it is indeed doubtful whether the fern or the giant grass is the greater pest, for after it has displaced a tangle of *uluhe*, it will encroach on the land still held by forest plants. A good example of such a dense bamboo forest may be seen below Koolau Gap, not many miles

from the boundary of the Haleakala Section of Hawaii National Park.

The Hawaiians in former times occasionally drank an infusion of the *uluhe* as a laxative.

TREE FERNS

Three kinds of tree fern are native to these islands. They flourish from almost sea level in the more rainy districts to an elevation of ten thousand feet or more. All belong to the family *Dicksoniaceae*. They can be readily recognized by their tall, upright trunks. The only plant that the visitor may possibly confuse with the true tree fern is the *Sadleria*, illustrated on Plate 11. The trunk of the latter, however, rarely exceeds five feet in height, while the frond is never as complicated in structure as that of the tree fern. In fact, an entire *Sadleria* frond resembles superficially merely one of the many large segments, or pinnae, composing a single frond of the other plant.

Menzies' tree fern, *Cibotium Menziesii* Hook., which is known to the Hawaiians as *hapu iii*, is the largest of our ferns. Its trunk may become twenty-five feet high, while the spreading fronds arising from its top may add another ten or fifteen feet to the plant's height. The lower third of the stalks of these fronds is always covered with very dark brown, almost prickly hair. Chamisso's tree fern, *C. Chamissoi* Kaulf., and its very close relative known as *C. glaucum* (Smith) Hook. & Arn., both called *hapuu* by the Hawaiians, are usually about ten feet shorter and the stalks of their fronds are without this stiff hair (Plate 6).

On the under side of many of the fronds may be seen small marginal bead-like structures called sori (Plate 6, at left). They are much more complicated than the simple sori of the *uluhe* fern previously described (p. 24). A small part of the margin of the frond has bent down to meet a flap of tissue arising from the under side. The resulting sorus, upon ripening, opens up like a purse near the middle to expose the well-protected sporangia. These, in turn, spring open to liberate into the air large numbers of microscopic reproductive bodies, or spores.

The buds of all three kinds of tree fern are densely clothed with brown, silky hair called *pulu* by the Hawaiians. This *pulu* of the tree fern, or the flowers of the sugar cane (p. 56), in the early days, was often used in embalming the dead. First the vital organs, throat, tongue and brain were removed. The resulting cavities



PLATE 6.—Tree Fern or Hapuu. (Original).
 Fragment of frond showing beadlike sori; cross section of trunk showing dark mass of roots,
 woody strands and starchy pith; one single frond with upper part of trunk at base.

were then tightly stuffed with the *pulu* and sewed up with *olona* (p. 197) fiber. The corpse was next wrapped in a black sheet of bark cloth, or *kapa* (p. 132), in which state it would remain little changed for at least eight months. It thereafter was usually either buried in the ground or secreted in some cave whose entrance was in some cases later sealed with cement-like volcanic ash. At times these remains were thrown into the surging lava lake of Kilauea in honor of Pélé, goddess of volcanoes, who was said to feed chiefly on human flesh.

By 1859 *pulu* was extensively gathered, especially from the *hapuu*, and shipped to California and elsewhere as material for stuffing mattresses and pillows. In 1869 alone, the amount of *pulu* derived from these ferns and from the *Sadleria* (p. 37) for export came to almost 623,000 pounds.* When this industry fortunately ended in 1885, these beautiful trees were no longer cut down to facilitate gathering the small quantity of *pulu* that each could furnish. Around 1920 the tree ferns were again threatened with destruction by the beginning of a fern-starch industry near Hilo. The trees were cut for the starch contained in their trunks. This was of very good quality for either laundry or cooking purposes. After a short time, the concern that manufactured the starch suspended operations.

Although an old tree fern may measure two or more feet in diameter at the base, only a very small proportion of this is actually taken up by the trunk itself. The greater part consists of intertwining aerial roots that arise from the trunk and gradually work their way toward the ground. These not only absorb nourishment for the plant, but also aid in supporting it in an upright position and in protecting the true trunk from injury. Because of this ability to produce abundant adventitious roots, the upper part of

* Export of *pulu*, in pounds, from 1867 to the present time:

1867	203,958
1868	342,882
1869	622,998
1870	233,803
1871	292,720
1872	421,227
1873	412,823
1874	418,320
1875	379,003
1876	314,432
1877	150,586
1878	212,740
1879	137,001
1880	44,846
1881	53,415
1882	
1883	
1884	465

Practically none since last date.

the tree fern will continue to thrive even after a considerable part of the trunk has been cut away below. Plants are therefore occasionally seen by visitors in Hilo and Honolulu, planted in gardens or ornamental tubs. In the vicinity of Kilauea, for example, they are commonly set in the ground in upright rows to form a delicate, living hedge as the new fronds uncurl. The bases of the trunks are used to pave rustic walks.

The cross-section (Plate 6) of a young tree fern stem has a light-colored central pith surrounded by several hard bands of wood. Enclosing all is a dark matrix filled with lighter circles and loops. These are the cut ends of aerial roots. In strata of the Carboniferous or Coal Period, stones have been found which, upon polishing, show similar designs, but in various brilliant hues. These are cut and made into brooches as Figure 11 shows, and sold by German

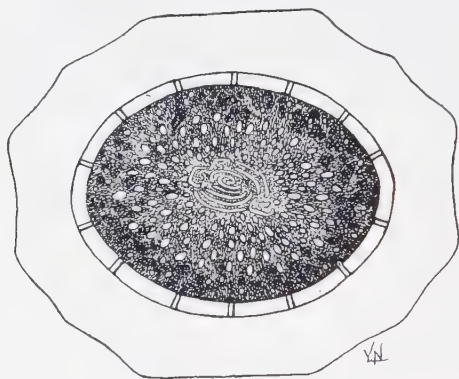


FIGURE 11.—Brooch made of fossilized tree fern trunk.

jewelers as *Staar-Steine*. A translation of this term is "Starling-Stones," an appropriate name because the fossil in its petrified rootlets somewhat resembles the speckled plumage of the European starling, a relative of the introduced false myna bird. The botanist recognizes the jewel as the remains of the trunk of an extinct tree fern, called *Psaronius*, of uncertain relationship to the Hawaiian plant.

As the pith of the *hapuu* trunk is rich in starch, it was freed of the surrounding fibrous roots and wood, and then cooked for food by the Hawaiians in the early days during times of famine. Not many years before the Kilauea region was created a National Park by Congress, large tree fern trunks, as well as the trunks of the *Sadleria*, were dumped into certain steam crevices in the neighbor-



PLATE 7. Pellucid Polypody or Ac. (Original).
Enlargement of pinna showing sori.

hood of the Volcano House. After they had been cooked by the volcanic heat they were fed to hogs to fatten them. The young, uncoiled fronds were occasionally cooked and eaten by the Hawaiians.

Two important animal enemies of the tree fern exist. The wild pigs, introduced by the Hawaiians centuries ago, uproot the plants and feed upon their starchy trunks. The other pest is a very small foreign weevil that now inhabits certain districts and bores into the stalks of many kinds of ferns. As this insect has no wings to enable it rapidly to extend its range of activity, the danger of introducing it into new regions would be greatly lessened if well-intentioned people refrained from transporting ferns from place to place, no matter how small the fragment. One of the few plants that sometimes destroys the tree fern, as described on page 232, is the *ohia lehua* tree.

HAWAIIAN POLYPODIES

The pellucid polypody (Plate 7), the *ae* of the Hawaiians, belongs to the fern family *Polypodiaceae*. It is very common in the open woods near Kilauea Crater. Here its pinnae, or frond segments, have a tendency to fold one against the other and to bear at the base an auricle, or prolongation. In certain other regions, however, the plants have fronds that are flat and have pinnae that lack auricles, or that vary in other respects. Botanists are not yet decided as to whether all these plants comprise one single kind of polypody that varies considerably under different conditions of soil, temperature and moisture, or whether there are half a dozen distinct kinds in these islands difficult to tell apart. Until further study has definitely settled this question, the plants may be provisionally known as *Polypodium pellucidum* Kaulf.

This plant has thick rootstocks, densely covered with brown scales, that usually creep over the ground. The fronds, about one foot long, are attached to the upper side of the rootstock by a basal joint and this is where they become detached when old and of no more value to the plant. Each frond bears numerous tongue-shaped pinnae. Upon holding one of these against the light, one will discern many transparent branching veins to which the definitive name of this fern refers. At the ends of these veins on the upper surface of the older fronds, a white spot may be frequently found. This consists of salts that are useless to the plant and are therefore expelled through a microscopic aperture, termed hyda-



PLATE 8.—Safford's Polypody. (Original).

thode, in the frond surface. The under sides of the mature fronds usually bear large, brown sori containing spores, or asexual reproductive bodies.

Safford's polypody, known scientifically as *Polypodium Saffordii* Maxon (Plate 8), is one of the smallest ferns peculiar to the Islands. It is partial to the moss-covered trunks and branches of trees in the damper forests above 3,000 feet elevation. Within the Kilauea Section of the Park this plant is not uncommon. Because of its small size and peculiar habitat, however, it usually escapes the attention of the visitor or is mistaken for one of the mosses among which it grows.

Safford's polypody has a very short rootstock from which numerous threadlike roots ramify throughout the surrounding moss and bark. The linear fronds, arising in a cluster from the upper part of the rootstock, are one to five inches long and but a fraction of an inch in width. They are notched into bluntly triangular lobes for all but their upper third, where the sori containing the reproductive bodies are located. These are borne on the under surface of the frond without any special protection. In this respect the plant resembles the pellucid polypody, indicating that both ferns belong to the same plant group.

PTERIS

Pteris vittata L., (Plate 9) was first collected in these islands in 1922. It was found in the vicinity of steam crevices near Kilauea. Eight years later, in company with the introduced silver fern, called *Pityrogramma calomelanos* (L.) Link, it had become one of the common plants wherever the warm, moist volcanic vapors reach the surface of the ground. This plant is native to the tropics of the Old World and quite different from *Pteris longifolia* L., of America for which formerly it was mistaken. The latter was not found growing, as reported by others, near steam crevices but on the wet cliffs at the Thurston Lava Tube.

Pteris vittata has bright green fronds. Its sori, as in all other kinds of *Pteris* of which about two hundred fifty are known, are protected by a flap of tissue, called the indusium, formed by the revolute margin of the frond. The various kinds of *Pteridium* or bracken, of which an endemic kind, known as *pai* or *kilaupūco* in Hawaiian, grows commonly in grassy localities in both sections of the Park, differ in having an obscure secondary indusium fac-



PLATE 9.—*Pteris*. (Original).
Single pinna shows sori partly protected by margin.



PLATE 10.—Cliffbrake or Kalamoho Lauili. (Original).

ing the marginal one. All these plants belong to the *Polypodiaceae* or Fern Family.

CLIFFBRAKE OR KALAMOHO LAULII

The cliffbrake (Plate 10), the *kalamoho laulii* of the Hawaiians, is known botanically as *Pellaea ternifolia* (Cav.) Link, and, like most ferns, belongs to the family *Polypodiaceae*. Our plant is native, not only to the Hawaiian Islands, but to warm and tropical America as well. This is not a true cliff plant as its name would indicate, but rather prefers to grow in very dry soil among ledges or embankments exposed to the full heat of the sun. It grows within the boundaries of both sections of the National Park and, though rare, has been found on the inner slopes of Haleakala Crater. Along the trail that leads from Kilauea to the summit of Mauna Loa it is rather abundant in spite of the livestock that is pastured where it grows.

This fern is characterized by a short, thick rootstock from which stiff, upright fronds arise that are usually less than one foot high. The stalks of these fronds are shiny and dark. The pinnae, or frond segments, have a bluish-green tinge. Each of the latter is divided in such a way as to resemble a leaf consisting of three leaflets, thus giving the entire plant the appearance of some strange clover. The margins of the segments are rolled under and hide the sori, or clusters of reproductive structures, from view. Although the fronds die with age and are replaced by younger ones, they long remain attached to the plant.

SADLERIA

Sadleria is the name of a group of ferns peculiar to the Hawaiian Islands. All have fronds of the character shown on Plate 11 and all belong to the family *Polypodiaceae*. The plants live under many different conditions: some near the sea, others on the summits of all but the highest mountains; some in dense rain forests, while others manage to survive on the newest and driest lava or on the rocky faces of canyons. Whether four or more kinds of *sadleria* exist in the Islands and live under one or more of these conditions is a problem that the botanist has not yet definitely solved.

The fern known as *Sadleria polystichoides* (Brack.) Heller, or *apu'u*, may be collected along the Olinda Pipe-Line Trail on Maui a few miles below the north-west boundary of the Haleakala Section



PLATE 11.—*Sadleria*. (Original).
Pinna showing lower surface.

of the Park. Here it grows only on the moss-covered perpendicular rocks and embankments forming the sides of the canyons. During rainy weather the plants are abundantly supplied with water trickling down the thin layer of moss but during fair days they are fully exposed to the blazing sun that dries them and their substratum. They are evidently very tenacious of life to be able to withstand such periods of drought and such seemingly unfavorable situations for growth. On some of the cliffs down which water seeps rarely, dwarfed specimens that have almost no rootstock and have fronds barely three inches long may be found in full reproductive vigor. Normal plants have a rootstock about three inches long and fronds two feet long.

At least two kinds of sadleria may be found in the vicinity of Kilauea, both having an upright trunk half a foot to five or, very rarely, even nine feet high. Hillebrand's sadleria, *Sadleria Hillebrandii* W. J. Robinson, called *amau* by the Hawaiians, is the less common. It can be seen growing in numbers, however, in the crevices between the Sulphur Banks and the Military Camp, as well as near the Thurston Lava Tube. Its fronds are usually about one and a half to two and a half feet long. Their stalks as well as the midribs are nearly always covered with brown scales, and the smallest veins may be distinctly seen on the under side of the segments.

The common sadleria, *S. cyathoides* Kaulf., is called *amaumau* by the Hawaiians. It usually becomes more than twice as large as the *amau*. It may be easily differentiated from the latter by the lack of permanent scales above the base of the frond and by the obscurity of all but the midrib in the smallest division of the frond. Between Kilauea and Glenwood several plants were collected that show features intermediate between those of *S. Hillebrandii* and *S. cyathoides* and are, therefore, thought to be hybrids. One of these unusual specimens is chosen for illustration in Plate 11.

The common sadleria is almost the first plant to grow on fresh lava flows as the late, unfortunate C. N. Forbes, botanist of the Bishop Museum, has shown. Its old decaying fronds and living trunk soon furnish a suitable bed for the wind-blown seeds of the *ohia lehua* (p. 232) to germinate. The *ohia lehua* seedlings finally develop into the trees so characteristic of the Islands. This fern may be found also in the Kau Desert near Kilauea where not even the desert silene (Plate 38) can survive the heat, dryness, and high concentration of salts in the soil. To be sure, the plants

bear only two or three depauperate fronds in the midst of a dozen dead ones that have accumulated over a period of many years.

A generation or two ago the soft scales protecting the buds of the common sadleria were gathered, as were those of the *Cibotium* (p. 29), and shipped to California as *pulu amaumau*. There they were used as stuffing for pillows and mattresses. Before the white people came with their manufactured cloth, the Hawaiians macerated the stalks of fronds of this fern and beat them together as a sizing with the bark of various plants in the making of their *kapa*, or bark cloth (p. 132).

The *amaumau* also furnished a red dye for their *kapa*. The outer part of the trunk was mashed and its juice was squeezed into a calabash, or vessel. To this red liquid, according to some authorities, salt was added to produce coagulation, while according to others no salt was used. Since the Hawaiians had no metal or earthenware dishes to enable them to boil liquids, hot stones were placed in the calabash to boil and to evaporate some of the water in order to concentrate the dye which was then ready for use.

The early name of the fire pit within Kilauea Crater, according to the Hawaiians, is *Lua Pele*, or the Pit of Pélé, goddess of volcanoes. A later name, and one less often used, was *Hale-maumuau*, meaning "the house of *amaumau* fern". This name was given to it either because of the presence of a lava cone, now gone, that somewhat resembled the temporary shelter built of *amaumau* by the Hawaiians on their visit to the region or, less likely, because of the former abundance of this fern on the floor of the Crater of Kilauea. Though the word for "everlasting" is also spelled *mau*, the two Hawaiian words are pronounced in an entirely different way, *mau* being a single syllable and *a-ma-u-ma-u* being many. "The House of Everlasting Fire", the English name for the center of activity in Kilauea, though very appropriate and worthy of retention, is consequently not a translation of the original Hawaiian one as popularly supposed.

The starchy pith of Hillebrand's sadleria, the *amau*, was cooked in the ground and eaten by the Hawaiians, though not as commonly as was that of the *hapuu* (p. 30). The young fronds were also cooked for eating, somewhat resembling asparagus in taste. In ancient times for planting vegetables, the Hawaiians covered the ground in the drier regions with *amau*, and probably also *amaumau* fronds. Then when they noticed that it would rain, they removed the fronds and planted their seed. After the rain, the

leaves were replaced as a mulch to hinder evaporation. This custom was so prevalent that it has given rise to the saying: "While rain clouds are still in the sky, remove the covering of *amau* fronds." *Amau* fronds, according to some Hawaiians and *amaumau* fronds according to others, were used for thatching the native houses (p. 269) when the more preferable *pili* grass (*Heteropogon contortus* (L.) Beauv.) was scarce, and were even used to cover the walls of the houses. Because of the difficulty of making the ridge of the roof and the corners where two surfaces joined rain-proof no matter what thatch was employed, a row of *sadleria* fronds was commonly tied lengthwise over it. The midrib, or rachis, of each frond was first slit on the upper side so that the fern could be made to lie flat on each surface of the roof. The ground which the king and his attendants were to pass over or remain on at the dedication of a *heiau*, or temple, was likewise covered with *amau* fronds.

SWORD FERNS

Two kinds of sword fern, members of the *Polypodiaceae* or Fern Family, may be found growing wild in the Hawaiian Islands. They are characterized by an upright, scaly, short rootstock from which arise long, pinnate fronds. These, if mature, produce sori consisting of a circular area of sporangia, or asexual reproductive organs, protected by an overlying kidney-shaped tissue called an indusium. This structure is so typical of these plants that they have been placed in a common group named *Nephrolepis*, meaning kidney-scale. In addition to reproducing by spores, these plants produce long, slender runners at the end of which young plants develop. These in time become detached from the parent by decay of the intervening connection.

Nephrolepis exaltata (L.) Schott, is native to tropical and subtropical countries of both the Old and the New Worlds. It is also native to the Hawaiian Islands where it is one of the commonest ferns, especially at lower elevations. The plants growing on the continents have long been favorites among horticulturists who have produced from them many different ornamental forms of which the Boston fern is the best known. This, in turn, has been modified still further into numerous kinds of crested and much-divided mutants or sports of considerable beauty of which more than fifty have been considered worthy of naming. Many of them have been introduced into the Islands as garden and potted plants.

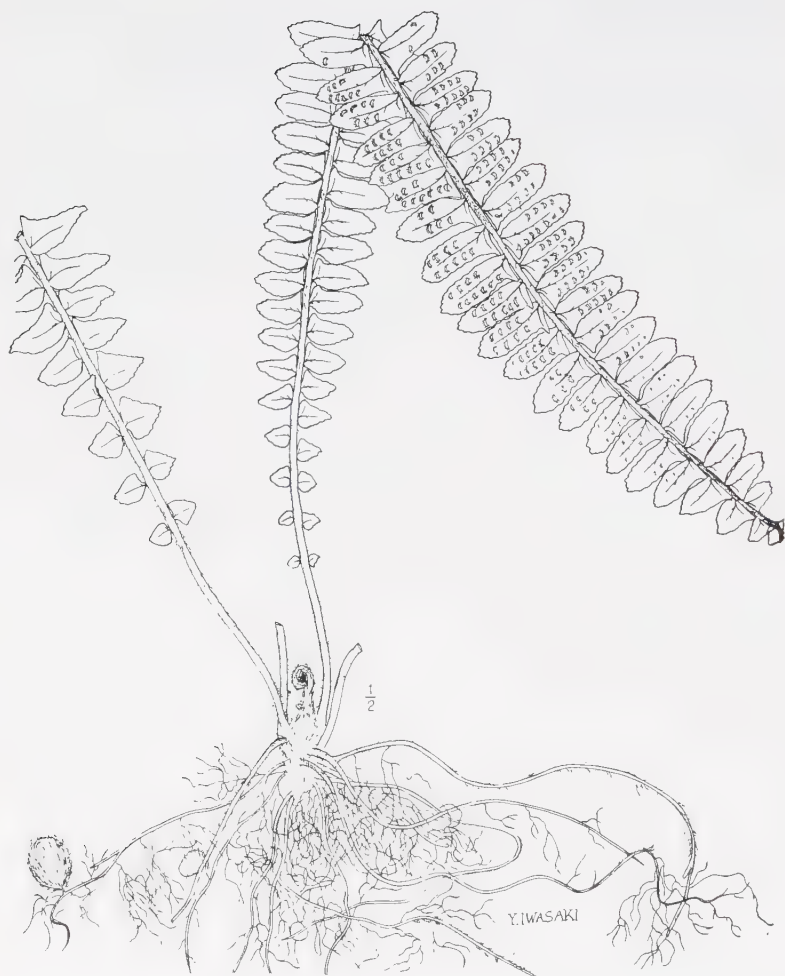


PLATE 12.—Sword Fern. (Original).

They occasionally escape and may be found growing with their wild relatives.

The typical native *N. exaltata* may be found in the Kilauea Section of the Park in great numbers along the Chain-of-Craters Road and near Napau Crater. It grows commonly on the ground and occasionally on moss-covered trunks of trees.

Nephrolepis cordifolia (L.) Presl (Plate 12), also of wide distribution, is not native to the Hawaiian Islands but was probably introduced as an ornamental from Japan previous to 1875. It also has escaped from cultivation and is definitely known as a naturalized plant from Oahu, where it was first collected by a Rev. Mr. Lyons and by J. F. Rock; from Mt. Eke of West Maui, where it was first collected by Degener & Wiebke in 1927; and from Hawaii, where it was first collected by the same botanists in 1929. On the latter island it is rather common on the trunks of trees and on the ground in the open forest near Makaopuhi Crater not far from Kilauea as well as on the slopes of Mauna Loa and Hualalai, and elsewhere.

The two sword ferns resemble one another so closely that few notice that more than one kind exists in the Islands. It is, however, not difficult to distinguish the two. *N. exaltata* has broader and flatter fronds than *N. cordifolia*. Moreover, the former has runners that are filiform throughout, while those of *N. cordifolia* frequently produce ovoid, scaly tubers as the bottom of the plate shows.

The native sword fern was known to the Hawaiians as *pamoho*, *nianiau*, or even as *okupukupu*. The plant was apparently of no special use to them.

SCREWPINE OR HALA

The pandanus or screwpine, known in the Hawaiian Islands by the native name of *hala* or *lauhala*, is botanically *Pandanus tectorius* Sol. This is a typical coastal plant found native throughout Polynesia and Malaya in several different varieties and forms. It and its close relatives, as well as two other groups of plants, constitute the *Pandanaceae* or Screwpine Family.

The *hala* is a peculiar tree ten to twenty feet high, having a short, erect, pale trunk bearing thick, forking branches (Fig. 12). As the enlarging crown of the plant soon becomes too heavy to be supported by the original trunk and root during wind storms, thick prop roots arise from the trunk, above the base, and not

infrequently from the lower branches. These slowly grow toward the ground, adding strength to the plant. Their delicate ends, where active growth takes place, are protected by a very conspicuous, papery root-cap. Other parts are armed with conical prickles arranged roughly in longitudinal rows. These structures are actually side roots that have become arrested in growth and modified into weapons of defense.



(Courtesy R. J. Baker)

FIGURE 12.—The screwpine or *hala*, a typical coastal plant.

The leaves of the *hala* are spirally arranged in tufts at the ends of the branches. On falling from their place of attachment they leave a permanent circular scar (See *hala* stem in Fig. 32). The leaves are linear, three to five feet long, and quite hard and firm. Their margins and the under side of their keeled midrib are beset with very sharp, forward-pointing spines.

In cutting the stems or branches of various *hala* trees one will observe that in some trees they are very hard and firm through-

out, while in others, on the contrary, they are hard near the outside and rather juicy and soft within. Around February when the *hala* are in flower, the reason for this difference in stem structure is clear. The trees are of two distinct sexes. Those possessing hard wood are staminate plants and produce staminate, or "male," flowers. Those possessing softer wood are pistillate plants and produce pistillate, or "female," flowers.

The staminate trees, called *halapia*, produce from the ends of their branches pendant series of large flower clusters (Plate 13, on right) called *hinano* by the Hawaiians, which are protected and made conspicuous by subtending, pale yellow bracts. Each cluster is composed of hundreds of pale yellow staminate flowers in which all floral structures have aborted excepting the stamens. A variable number of these are united by the lower part of their stalks into the oblong flowers. All, together, shed an enormous amount of pollen which is sought by bees and various other insects as food. These pollen-filled flower clusters were sometimes gathered in former times by Hawaiian maidens for the purpose of playfully belaboring the youths of their choice on the supposition that the pollen would act as a love charm. The pollen was also at times seriously collected and used as an aphrodisiac.

The pistillate trees produce from the ends of their branches a single compact flower cluster surrounded by bracts. This greenish structure gradually increases in size until it becomes about as large as a child's head. In studying it at this stage (Plate 13, on left), one can see how complex it really is. It is not a single fruit at all, but is built up of 250 to 800 fruits that are firmly grown together into oblong and somewhat angular units, termed phalanges, composed of one central fruit surrounded by four to ten others. Fifty to a hundred of these phalanges in turn form the sphere which is consequently a collective fruit.

The *hala* is remarkably well adapted for dissemination. Each phalange when ripe is bright orange toward the basal end, and fragrant and quite fibrous-fleshy on the outside. Within, it is so extremely hard and woody that the centrally located seeds on germinating could never force their way to freedom. Consequently a channel of less resistant and more spongy material leads from them to the surface through which the seedling can grow. In addition to these spongy channels, similar areas are scattered in the phalange.

The color and especially the fragrance of the phalange attract



PLATE 13.—Screwpine or Hala. (Original)
 Old pistillate flower cluster and various views of phalanges, entire and sectioned; staminate flower cluster and single staminate flower; part of leaf.

rodents and other animals which feed on the sweetish pulp. The woody tissue within, on the contrary, sometimes prevents them from eating the seed. In this way the plant may be disseminated by animals on land. In case the phalange, especially when old and dry, should be borne into the sea, then the spongy areas function as a float. Thus the phalange, after being buffeted around by waves and currents, may at length be thrown on some distant shore where the seeds it contains may germinate.

The ripe phalanges, after the pulp had decayed or been purposely removed, were used by the Hawaiians as brushes, called *huluana'i*, in staining their *kapa* (p. 137), or bark cloth, with dyes. The seeds were also occasionally eaten, though hardly worth the labor of freeing them of the surrounding wood. The orange flesh was only rarely eaten, as, for instance, during times of famine, because it contains a considerable number of raphides, or crystals, that cause irritation as do those in raw taro (p. 79). Other kinds of *hala* native to the South Seas contain so few raphides in their phalanges that their pulp is a staple food of the natives. In the making of garlands, or *lei*, the Hawaiians with a shark's tooth cut the basal third of the orange phalange into fragrant discs often serrate at the upper edge. It was considered ill luck to wear one of these *lei*.

The greatest value of the *hala* was in its leaves, known as *lauhala*, a name often given to the entire plant. Houses (p. 269) were frequently thatched with them, the ridges and corners usually being capped with dry *ama'u* (p. 41) fronds or with *la-i* (p. 97) leaves. The leaves of the *hala* were plaited into baskets and into mats, the commonest of floor-coverings (Fig. 13). Ordinarily the dead leaves were gathered from the ground. With a knife consisting of the sharp-edged *papaua*, or *pahiaku*, shell to which a wooden handle had been tied, the flaring bases, the pointed ends and the teeth were cut away. If the entire width of the leaf was desired, then the midrib was scraped with the shell instrument until no thicker than the rest of the leaf. If the full width was not wanted, the leaf was torn in half lengthwise and the midrib discarded. The leaves, whether of the full width or half width, were then rolled lengthwise to prevent wrinkling and set aside to dry. If the leaves were to be of a dark color, this drying was accomplished in the shade of the house; if light, then in the sun. When ready to begin plaiting, the leaves were brought forth from storage and torn into strips an eighth of an inch to

one and one-half inches wide, according to the grade of mat desired.

This general procedure was often modified. For example, to produce a superior quality of mat, living leaves were gathered instead of dead ones, and these might first be passed through a flame to wilt them. At times the Hawaiians combined in their mats for the purpose of ornamentation not only leaves cured in one or more ways but the leaves of the *hala ulaula*, also known as



(Courtesy R. J. Baker)

FIGURE 13.—Hawaiian woman, wearing *holoku*, plaiting mat of *hala* leaves.

hala polapola. These, on drying, turned to a rich reddish-brown. This kind of *hala*, according to tradition, was brought at the same time as the pig from the Society Islands by Hawaii Loa, the legendary navigator who sailed at least as far as China and Chili, according to unpublished Hawaiian *mele*, or epics. For *hala* mats of especially fine texture and almost white color, living leaves were gathered and boiled until they had swollen and softened. These were next flattened with a stick until of uniform thinness, and hung up to dry. To produce mats, on the other hand, of a peculiar reddish hue, fallen leaves were used that had been dipped in a dye made of burnt coral boiled with the bark of the *noni* (p. 282) root.

Settees, called *koki*, for sleeping were also woven of *hala* leaves. The *maa* (p. 76), or sling, used in warfare was sometimes made of the leaves, though more commonly of human hair or of coconut fiber. The most delicate of the white flowering bracts of the plant were woven into garments called *ahuhihano* of marvellous flexibility and fineness. The coarser bracts and the young leaves, on the other hand, were woven into canoe sails called *peá* or *kalepa*.

CLIMBING SCREWPINE OR IEIE

The climbing screwpine (Plate 14), or *ieie* of the Hawaiians, is botanically known as *Freycinetia arborca* Gaud. It is common throughout the Hawaiian Islands in the forest, especially at lower elevations. It is not known elsewhere, but thirty or more related kinds are found in the islands to the southwest of us and in the Orient. All belong to the *Pandanaceae* or Screwpine Family.

The *ieie* is very conspicuous along the highway from Hilo to Kilauea Crater during the summer when it is in bloom. Some plants climb the trees and reach their very tops, the main stem gripping the trunks with its slender aerial roots while the branches curve out into the sun. Other individuals trail on the ground in great masses, forming impenetrable jungles.

The woody, yellow stems of the *ieie* are about one inch in diameter and ringed with the scars of fallen leaves. They produce numerous, long, adventitious air-roots of almost uniform thickness throughout, which not only gain nourishment for the plant but enable it to hold on to its support. The stems branch every few feet to produce terminal clusters of slender, shiny, green leaves. These are pointed at their ends and spiny along their edges and on the lower side of the midrib.

All plants mentioned in this guide, excepting the psilotums, lycopodiums and ferns, must have pollen, which is produced in their stamens, conveyed to their pistils in order to mature seed. But to produce seed that will develop into especially vigorous offspring, the pollen of one individual, in most cases, should fall on the pistil of another of the same kind. Plants have therefore gradually evolved various, often fascinating, methods for insuring such cross-pollination. Some plants, like the grasses, sedges, coprosma (p. 280) and plantain (p. 271), employ the wind for this transference and hence have inconspicuous, odorless and nectar-free flowers. Others, most of the kinds here illustrated, depend

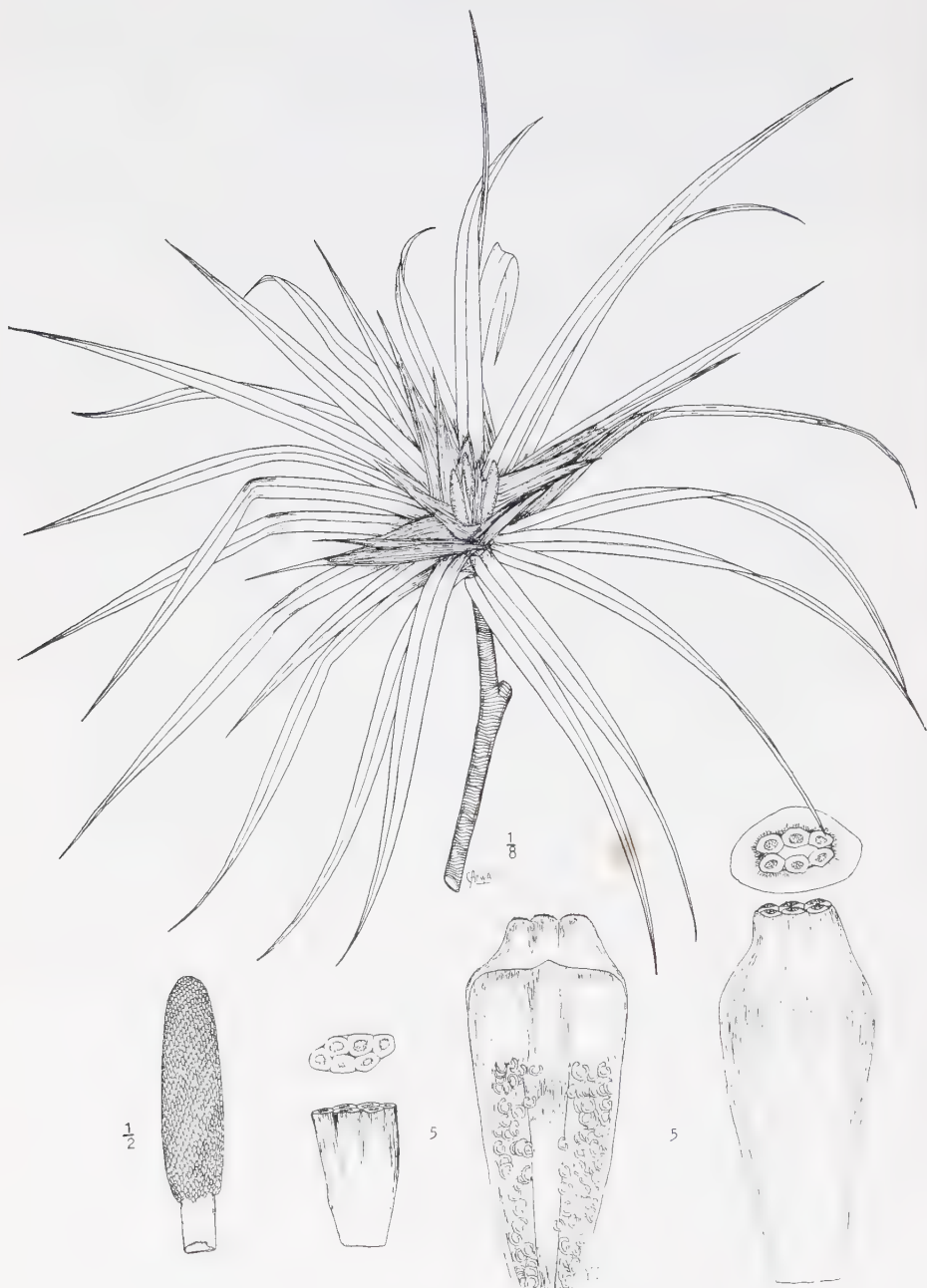


PLATE 14.—Climbing Screwpine or Ieie.

Staminate flowering branch; complex pistillate flower cluster; simple pistillate cluster when young and same, when fruiting, in longitudinal section to show seeds, and entire.

on insects instead to effect this transfer. They therefore bear flowers that contain nectar as a bait to lure the insect, and that are fragrant and conspicuously colored to enable the insect to find this bait with greater certainty. The special method that the *ieie* has devised to insure cross-pollination is so unusual as to be worthy of more detailed discussion.

At flowering time the ends of certain branches of the *ieie* develop about a dozen bright, orange-red leaves called bracts. These are fleshy and slightly sweet near the base. Within them stand three brilliant cones, or inflorescences, one of which is shown on the left of Plate 14. Each is composed of hundreds of flower clusters, each cluster consisting of about six united flowers of which nothing remains excepting their pistils firmly grown together. On entirely different individuals, of which the leafy specimen depicted on the plate is an example, similar showy bracts occur, also containing cones. These, instead of bearing pistils, bear only stamens that shed pollen. The *ieie* has thus prevented all possibility of self-pollination by bearing its two sexes on two separate kinds of plants namely, "female" or pistillate, and "male" or staminate. How the *ieie* solved the problem of having the pollen transferred from the "male" plant to the stigmatic end of the pistil of the "female" plant can be learned by studying the plants near Hilo and similar ones along the Chain-of-Craters Road near Makaopuhi Crater.

In viewing the matured flowering branches growing there, one will find them almost invariably mutilated—most of the fragrant, colored, fleshy bracts have disappeared. They have been eaten by rats which, in their quest for food, climb from flowering branch to flowering branch. In eating the fleshy bracts, the whiskers and fur of the rodent are covered with pollen, some of which undoubtedly rubs off on the stigmas of "female" plants visited later. The *ieie* is the only plant in the Hawaiian Islands and one of the very few in the entire world that uses mammals to effect pollination. Some of its relatives are pollinated by the flying fox, a kind of fruit-eating bat, that enjoys the bracts. The New Zealand plant, *F. Banksii* A. Cunn., bears such palatable bracts that even the natives eat them as a delicacy.

The Hawaiians in the early days made considerable use of the *ieie*. The fibers of the stem, after pounding and scraping, were extensively used as cordage to bind together the rafters of their grass huts and the outriggers to their canoes (p. 177). They

wove the strong, slender roots of the *ieie*, either whole or split in half lengthwise, into very durable baskets and into funnel-shaped traps of very fine mesh suitable for catching shrimp and small fresh-water fish. They were also plaited into helmets, called *mahiole* (Fig. 14), which were worn by the chiefs only in battle.



FIGURE 14.—Hawaiian warrior wearing a *mahiole*, or feather helmet, and a feather war cloak.

Tightly fitted over the helmet was a net of *olona* (*Touchardia latifolia* Gaud.), to which both red and yellow feathers were attached to form definite designs. The red were derived from the *iivai* (*Vestiaria coccinea* Forster) while the yellow usually came from the *oo* (*Moho* sps.). Idols (Fig. 15) were fashioned in a

similar way as were helmets. These consisted of plaited heads covered usually with the red feathers of the *iiwi* to which the yellow and black of the *oo* were added to emphasize the features. The eyes were often of mother-of-pearl with spheres of the dark wood of the *kauila* (p. 204) to represent pupils. The teeth were those of dogs. These horribly gorgeous heads were carried into battle by the priests on poles of *kauila* wood. Even the branches of the *icie* were much used as decorations, particularly where the dancing of the *hula* took place.

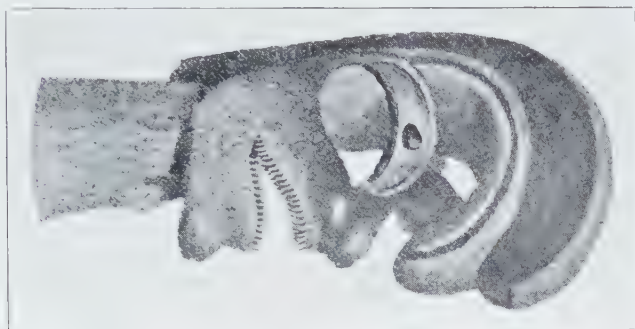


FIGURE 15.—Hawaiian feather idol.

The ancient *hula* had a religious significance and was therefore connected with definite *kapu*,* or "taboos." It was performed by professional dancers (Fig. 16) who had been obliged to undergo rigorous training. But because of the renunciation of the old gods, the breaking of the *kapu* and the coming of the foreigners, the *hula* gradually degenerated until today it is often little better than a vulgar spectacle. We owe to N. B. Emerson the valuable recording, translating and annotating of the various songs and customs connected with the real *hula* in his "Unwritten Literature of Hawaii."

In the early days a definite site was chosen and then purified by being sprinkled with sea water mixed with turmeric or with red earth often brought from Kauai. Here was constructed the *halau* or place where the pupils were taught the dances. This was strewn with rushes. It was considered a sacred structure. Within stood three huts or shelters, in one of which was a raised altar, or *kuahu*, dedicated to Laka, the goddess of the *hula*. While the *kumu*, or teacher, chanted one of several appropriate

* Due to unfamiliarity with Hawaiian speech, the early voyagers misspelled this word as "taboo," and thus it has become incorporated into the English language.



FIGURE 16. Hula dancer bedecked with *lei*, or garlands, and wearing *pau*.

prayers to Laka, the initiates decorated the altar with the flowering branches of the *ieie*, as well as with certain ferns, *maile* (p. 249), and possibly with *ohia lehua* (p. 230), *hau* (p. 213), breadfruit (p. 124), banana (p. 105), *la-i* (p. 95), *aalii* (p. 199), and *ilima* (p. 209). An uncarved block of hard, white wood from the sacred *lama* tree (*Maba* sps.) was wrapped in yellow *kapa*, scented with turmeric, and conspicuously placed upon the altar to symbolize the goddess. Besides the teacher, or *kumu*, connected with the *hula* school, there were two types of pupils and several special officers. The *olapa* were the young initiates who were best fitted because of their youth and grace to move actively in the dance and to pose and gesture. The *hoopaa*, on the contrary, were the older men and women who handled the heavier instruments and acted their parts usually while sitting or kneeling. In case the *kumu* were absent, his assistant, called *kumu kokua*, took charge. The *poopuaa* was an officer chosen by the pupils. He executed the *kumu*'s commands, collected fines and exacted penalties. He carried presents, such as garlands and *awa* (p. 122), to the *kuahu*. The *poopuaa* had an assistant, *pacpac*. During the construction of the altar, the *poopuaa* stood on the right while the *pacpac* stood at his left. The *hoonlu* was a guard stationed at the entrance of the *halau*, who sprinkled everyone with sea water and turmeric who desired to enter. He also kept order and daily placed a fresh bowl of *awa* on the altar.

As the time arrived for graduation from the *hula* school, the discipline was tightened and no pupil was allowed to leave the *halau* except for the most urgent reason and then only if his head was muffled as a disguise. The day before the *ailolo* ceremony, special songs and dances were held. Then, some time after midnight, the entire company, except the teacher, marched to the ocean to bathe and purge itself of any possible ceremonial impurity. This procession was made in complete nudity for religious reasons. Upon entering the *halau*, each person was sprinkled with holy water. This rite was followed by another period of dance and song when the *kumu* went into the sea alone to bathe. During his absence the *kumu kokua*, or assistant, was in charge of the *halau*. Before being allowed to reenter the *halau*, the *kumu* recited the password. More songs and dances followed before the company retired for sleep.

At daybreak the dancers recited a prayer before the altar and then reclined to their breakfast, to which friends, relatives, and

hula experts had been invited. The *ailolo* offering, consisting of a black suckling pig without a blemish, was then brought in and held down by the *kumu*. The hands of the pupils were laid on their teacher's hands while they consecrated themselves to their work. The pig was then taken out of the *halau* and prepared for the *imu*, or underground oven (p. 113). The *halau* was strewn with fresh rushes and the *kuahu*, or altar, was dismantled, another being built in its place and decorated with fresh material. The *kumu* now granted special dispensation to the pupils, who retired to groom themselves, for which they had had little opportunity during their strict confinement to their studies for weeks or even months. Anointed and bedecked with wreaths, the pupils entered the *halau* at the appointed time, being sprinkled as usual with consecrated water at the entrance.

The cooked *ailolo* pig was then brought in and placed on the *kuahu*, or altar, while the school sang songs of praise to the goddess Laka. At the conclusion of this service, the novitiates removed their wreaths and heaped them on the altar. Now the ceremony of *ailolo* began. Each novitiate received an equal share of the pig's snout, ears, feet, tail, portions of the vital organs, and especially the brain. This last, called *lolo* in Hawaiian, gave the name to this ceremony. These were eaten as a sacrament while the visitors sang praise to Laka. Thereafter the *kumu* lifted the *kapu* with a prayer, and the entire assembly indulged in the feast that was spread in the *halau* for them. On this occasion, men and women were permitted to eat in common (p. 110). A few more songs and prayers followed, and the students were graduated from the school. Soon after, these new *hula* dancers passed out of the *halau* and performed their *début* before the assembled multitude. From now on they could dance wherever they desired, free from all restrictions.

SUGAR CANE OR KO

Sugar cane, *Saccharum officinarum* L., and its relatives, are members of the Grass Family, termed *Poaceae* by some botanists and *Gramineae* by others. To the Hawaiians, sugar cane is known as *ko*. This giant grass has stems of rather uniform thickness filled with a sweet pith and marked off into prominent joints called nodes. These bear linear leaves and axillary buds in alternate arrangement. Like maize, or Indian corn, sugar cane at maturity produces tassels (Plate 15) that are hairy and silver-gray with a

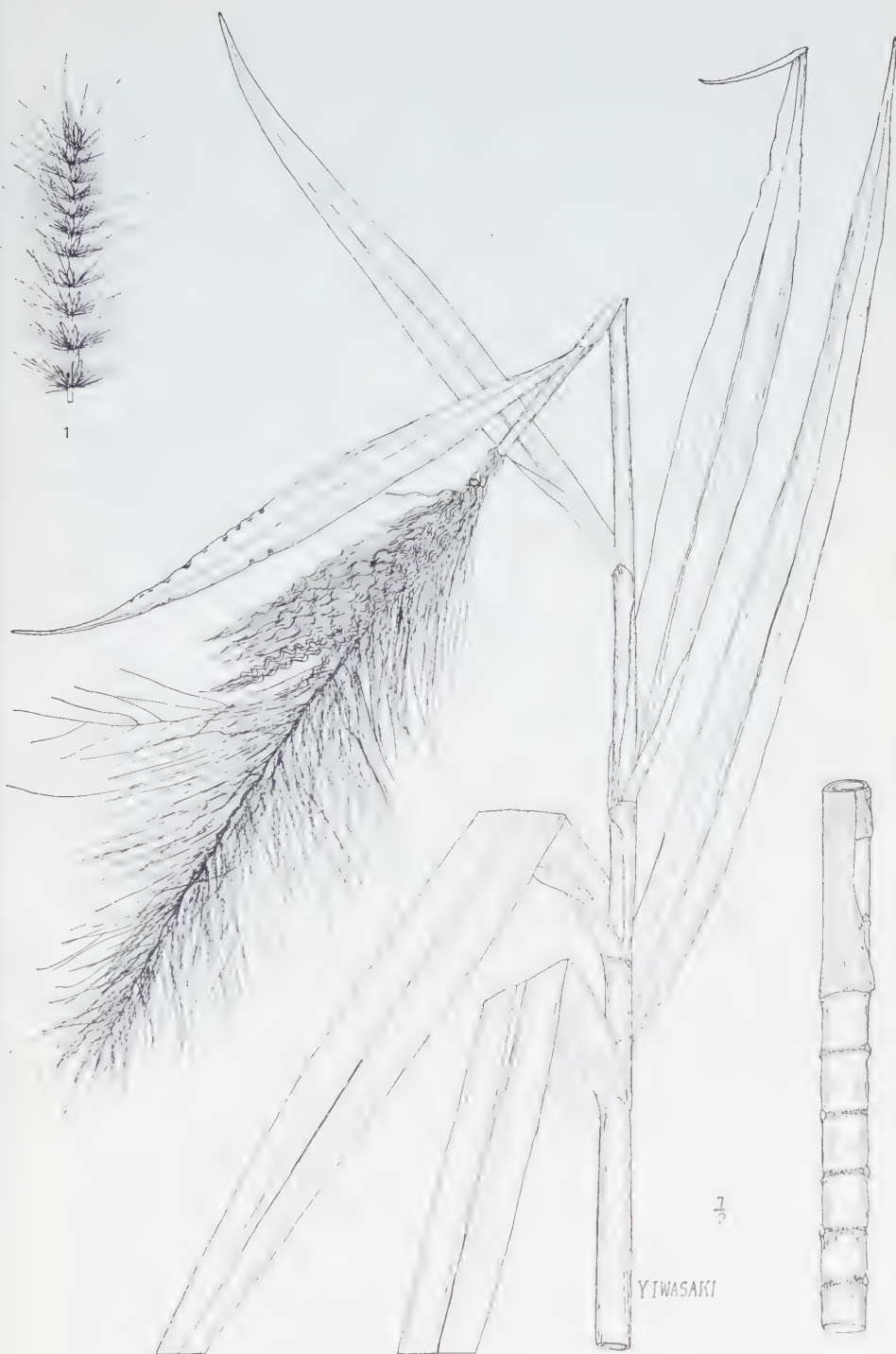


PLATE 15.—Sugar Cane or Ko. (Original)

reddish tinge. But unlike maize with its terminal tassel of "male" flowers and its axillary fused tassel or "ear" of "female" flowers that develop into grains of corn, the sugar cane bears terminal tassels only. These normally develop bisexual flowers, namely flowers having both stamens, or "male" reproductive organs, and pistils, or "female" reproductive organs.

Sugar cane probably originated in southern Asia, though exactly where, is not known. Chinese writers of the eighth century B. C., however, record its importation into their country from India. The plant, in many different varieties and forms, grew in most of the South Sea Islands previous to the coming of the white race, undoubtedly purposely transported by the Polynesians during their migrations. Even a hundred years ago the Hawaiians usually carried pieces of cane as a convenient portable and concentrated provision during their travels on land and water, just as the American Indian was accustomed to carry maple sugar for the same reason. Before Captain Cook's coming, the natives in the Hawaiian Islands cultivated the cane in a crude way, even within the boundaries of the Kilauea Section of the Park, like the taro (p. 79) and the banana (p. 109). As with many cultivated plants, they distinguished more than a score of kinds by special names. This classification was based largely on the color of the stem, but also to a lesser extent on its texture. Thus the *kokca*, *lahi*, *oliana* and *uala* have pale-yellow to greenish stems; the *honuaula*, *koelecle* and *papaa* have dark-red to purple stems; the *ainakca*, *akilolo*, *laukono* and *manulecle* have variegated stems; and the *puaole*, a cane that was the most vigorous and contained the sweetest juice but which seldom if ever flowered, was intermediate in stem color between the purplish and the variegated types. The *laukono* and the *manulecle* were used as aphrodisiacs by the *kahuna*, or sorcerer; the *koelecle* as a medicine in childbirth; and the *kokca* preferably for munching out of hand, because of its thin rind. Many of these horticultural forms have become extinct.

Besides its use as food and medicine to the early Hawaiians, the cane plant was important to them in several other ways. Its leaves were occasionally used to thatch their houses (p. 269). Sometimes the dead were embalmed by wrapping in *kapa* (p. 132) with the flowers of the *koelecle* sugar cane or with the *pulu* of the *hapuu* (p. 27) fern. As a sign that the plants in a field were *kapu*, or not to be taken by the common people, it was sufficient for a chief to place a stick of sugar cane in its corner.

The dried tassel with its basal stalk, in all about two feet long, was used for darts by children and adults in playing the game of *kea pua*. The lower end of the dart was tightly bound with string, wetted in the mouth, and then thrust into the earth to become coated with clay. The players in turn ran forward in a stooping position from a slight mound and, with a downward and forward swing of the arm, threw the arrow at such an angle that it just grazed the surface of the ground. From here it occasionally glanced gracefully like a flat stone thrown to skip over the surface of a body of water.

The sugar industry in the Islands had a very modest and desultory beginning, in which many races of man have had a part. A Chinaman, coming to the Islands in 1802 on one of the Chinese vessels to trade for sandalwood (p. 145), brought with him a stone mill for crushing cane and a boiler for concentrating the expressed juice. This primitive sugar mill, after grinding one small crop on the Island of Lanai, was abandoned when the owner returned to his native land. Don Francisco de Paula Marin (p. 276), the Spaniard who probably first recorded the growth of coffee (p. 276) in the Islands, made sugar for the king in Honolulu seventeen years later. Lavinia, an Italian, made sugar in 1823 by pounding the cane like *poi* (p. 82) with a stone beater on a wooden trough and boiling the juice in a small, copper kettle. John Wilkinson, an English gardener whom Governor Boki (p. 146) of Oahu brought to the Islands to stimulate agriculture, set out 100 acres of cane and coffee in the summer of 1825. This was planted on the governor's land in Manoa Valley, now part of Honolulu, by the natives with their *oo*, or primitive wooden diggers, for a wage of 25 cents per day. Though the plantings grew vigorously, they were abandoned on Wilkinson's death in 1827. The following year Antonia Silva, a Portuguese, made sugar at Waikapu, Maui, where he had erected a crude mill. In 1835 Ladd & Co., a firm which on its failure involved the Hawaiian Government in considerable difficulties, received a grant of land at Koloa, Kauai, from the king for the planting of cane. This was the first successful sugar enterprise in the Islands on a large scale. Two years later the first sugar and molasses were exported. Around 1840 about a score of sugar mills were in operation, two run by water power and the rest by bullocks.

With the gold rush in California in '49, agriculture in the

Islands was greatly stimulated. Not only sugar produced in the lowlands but even wheat and potatoes grown on the slopes of Haleakala were exported to the miners. Due to the decline of the native population and the large number away from the Islands on whaling vessels, as well as to the exodus of many white men to California in search of gold, the shortage of laborers for the local plantations became acute. This inaugurated the importation of men from many foreign countries. The first to come were 195 coolies from China. They arrived in 1852 and proved so industrious that more were desired by the planters with the result that by the time of the annexation of Hawaii in 1898 to the United States, 37,000 Chinese had come to the Islands. Fearing that the native population of the Hawaiian Islands would be supplanted by an alien race of Caucasians and Orientals, the king tried to recruit Polynesian laborers. Consequently in 1859 ten South Sea Islanders were brought here, and during the following twenty-five years more were imported from various islands to a total of about 2,000 men. As some of the Polynesians did not prove very satisfactory as laborers, other peoples were tried. In 1868 the first Japanese laborers came as a little band of 148 men. They, however, were not the first men of that nationality to reach these islands in historical times, some shipwrecked fishermen finding asylum here as early as 1832. Then with the signing of the reciprocity treaty in 1876, which admitted all unrefined sugars from the Islands into the United States free of duty, the industry enjoyed a period of unprecedented prosperity. This still further increased the demand for labor.

In 1878 the Portuguese began to come in large numbers. Many of them hailed from Madeira and the Azores where, in many cases, they are more or less mixed in blood with continental and other stocks. In 1881, about 600 immigrants came from Norway and about 125 men, women and children from Germany. Most of these Germans settled on the Island of Kauai. The next group of Japanese that arrived in the Islands after those of 1868 were about 2,000 who came in 1885. From that time on to 1907 Japanese immigration was continuous, the largest number of immigrants of that nationality for one year being almost 20,000. In 1903 the first Koreans came expressly as plantation laborers, in 1907 the first Spaniards to the number of 2,246, and two years later the first Russians. Porto Ricans, many of divers racial stocks, also added their quota to the population. In 1906 the first Filipinos came and from that time on immigration from those

islands has been continuous. By 1926 about 25,000 Filipinos were working in Hawaii, emigrants chiefly from the agricultural districts of Ilocano and Visayan. Thus the sugar industry is largely responsible for having prepared a unique field for the study of interracial relations and eugenics, involving the peaceful amalgamation of four great races of mankind and many subsidiary races. It is



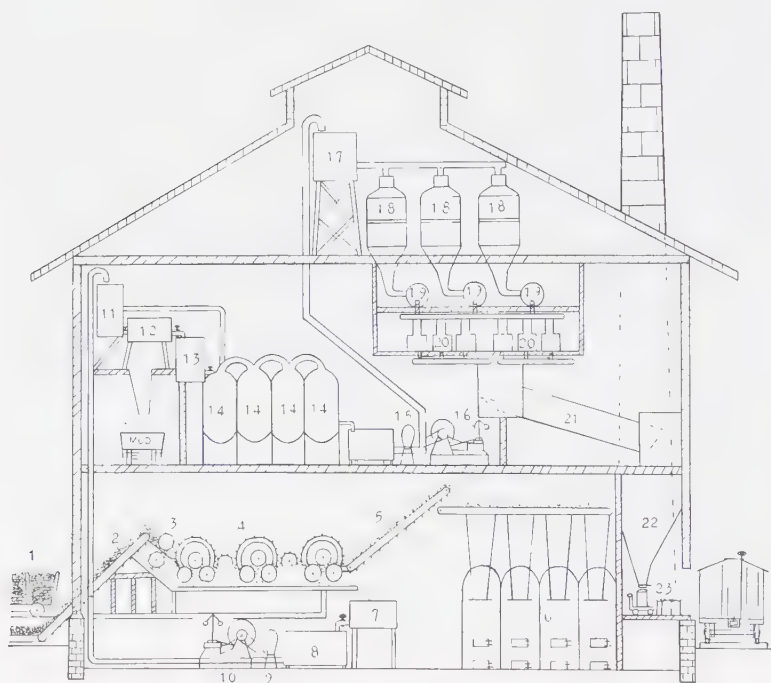
(Courtesy R. J. Baker)

FIGURE 17.—Sugar cane bearing tassels containing the flowers

amazing that this most important science has not long since been represented in the Islands by an institution of trained specialists to concentrate solely on all phases of this one subject.

While the proportion of different races of man inhabiting the Islands was thus changing, the different races of sugar cane here likewise changed. During the latter part of the nineteenth century,

if not before, many of the old native canes were gradually being displaced by more productive kinds. Their origin failed to be recorded in many cases. One of these early commercial canes, popularly called by the Hawaiians *ko-pake*, was most likely imported by the Chinese, probably during the time of the sandalwood trade (p. 145). Another, called Lahaina cane because it was first extensively grown in that vicinity on Maui, was imported from Tahiti on the ship "George Washington" in 1854. This cane soon became very popular because of its high sugar content, hard rind resistant to many insect injuries, and rapid growth. It displaced most of the earlier types grown on the plantations. Then a root disease began to attack the plants, thus threatening the entire industry with failure. Cane comparatively immune to this malady, such

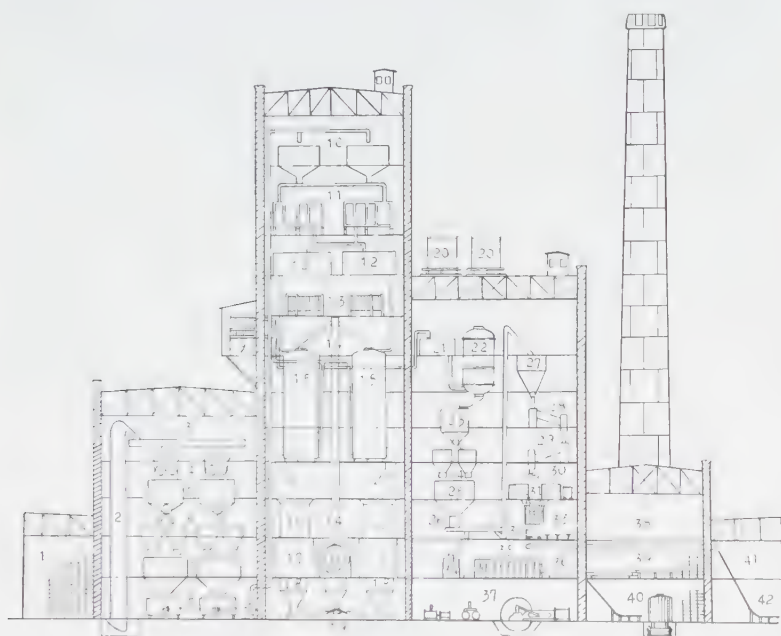


(Adapted from W. T. Pope)

FIGURE 18.—Diagram of process for deriving raw sugar from cane.

- | | | |
|-------------------|-------------------|--------------------------|
| 1. Car with cane | 9. Pump | 17. Syrup tank |
| 2. Elevator | 10. Engine | 18. Sugar pans |
| 3. Crushers | 11. Settling tank | 19. Centrifugals |
| 4. Rollers | 12. Mud press | 20. Centrifugals |
| 5. Trash elevator | 13. Reservoir | 21. Drier |
| 6. Furnaces | 14. Evaporator | 22. Sugar bin |
| 7. Liming tank | 15. Pump | 23. Sacking and weighing |
| 8. Juice tank | 16. Engine | |

as the kinds known as Yellow Caledonia and H-109, was therefore planted in its stead. The latter is one of 5,000 seedlings developed by the experiment station of the Hawaiian Sugar Planters' Association. It proved to be far superior to other forms of cane in many respects and, consequently, is widely grown. As the experiment station succeeds in breeding still better forms, the older canes, in turn, will be abandoned. By breeding, by the control of insect and fungus diseases, by improved methods of culture and of application of fertilizer, as well as by improved processes of sugar manufacture, the average local production of sugar per acre has



(Adapted from *Story of Sugar in Hawaii*)

FIGURE 19.—Diagram of process for deriving refined, white sugar from raw sugar.

- | | | |
|---------------------------------|------------------------------|------------------------------|
| 1. Raw sugar warehouse | 15. Bone char filters | 30. Powder mill |
| 2. Raw sugar elevator | 16. Bone char driers | 31. Screens |
| 3. Raw sugar conveyor | 17. Bone char kilns | 32. Automatic scales |
| 4. Raw sugar crushers | 18. Bone char coolers | 33. Sewing machines |
| 5. Mixers | 19. Bone char conveyors | 34. Cube machine |
| 6. Centrifugal washing machines | 20. Water storage tanks | 35. Cube drying ovens |
| 7. Storage bins | 21. Pan storage | 36. Cube conveyor |
| 8. Melt tanks | 22. Vacuum pans | 37. Pump and engine room |
| 9. Liquor troughs | 23. Mixer | 38. Bag sewing room |
| 10. Blow-up tanks | 24. White sugar centrifugals | 39. Small package department |
| 11. Filters | 25. Storage | 40. Shipping department |
| 12. Storage tanks | 26. White sugar conveyor | 41. Refined sugar warehouse |
| 13. Filters | 27. White sugar storage | 42. Shipping department |
| 14. Bone char elevator | 28. Sweaters | |
| | 29. Granulators | |

steadily increased from less than one ton for the crop of 1850 to 4.75 tons for the crop of 1900 and to 6.50 tons for that of 1925. The amount of sugar obtained per acre of cane in the latter year ranged, however, from 2.50 to as much as 18 tons.

Today sugar cane is planted in the Islands from near sea level to an elevation of about 2,000 feet. It is the usual practice to plow the land to a depth of one and a half to two feet. This is done with a tractor or, more commonly, with two steam engines spaced 1,000 to 1,500 feet apart in the field. These drag a reversible gang plow back and forth between them by means of a steel cable. For planting, furrows eighteen inches deep and spaced five feet apart are opened and into them a continuous line of so-called "seed pieces," better known by the Hawaiian name *pulapula*, is laid. Each piece, preferably taken from near the top of the harvested stalk of cane, is about one foot long and carries at least two nodes with their attached buds. The *pulapula* then is lightly covered with soil and, on irrigated plantations, a stream of water is run over the top. In about a week a continuous stand of buds breaks through the surface of the soil. This cane is fertilized, irrigated and cultivated from time to time. While it is young, the weeds are killed by hoeing them or by spraying them with a poison made of arsenic and caustic soda. This latter practice necessitates the posting of warnings along adjoining roadsides such as "poison grass." As the cane increases in size and shades the ground, weeds become less troublesome. Several months before the time of harvesting, irrigation and fertilizing are reduced or entirely discontinued to concentrate the juice in the plant. Then in fifteen months to two years after the initial planting, the cane may begin to flower (Fig. 17) and may be ready to harvest. This flowering usually occurs in November and December. The fields with the cane still standing are commonly burned over to rid them of as many dead leaves as possible and thus to lighten the labor of handling the crop. Thereupon the blackened stalks of cane are cut as near the ground as possible and, after the top has been removed, are ready for delivery to the mill. Transferring the rod-like canes to it is accomplished in several ways, depending upon local conditions. They may be placed in portable board flumes and floated to the mill; or they may be piled into railroad cars on temporary tracks laid in the field and hauled to it; or, along the Hamakua coast of the Island of Hawaii, they may be tied into 175-pound bundles and sent to it by gravity over cables.



PLATE 16. *Gahnia*. (Original).

At the mill, the cane passes through crushers that express the juice. The refuse, called bagasse, then falls into the furnaces to be used as fuel or is saved for the manufacture of wallboard and mulching paper (Fig. 24). The expressed juice, on the other hand, is subjected to various processes to extract from it the "raw sugar." The latter is then usually shipped to California to be refined for the consumer's use. The simplified diagrams of mill (Fig. 18) and of refinery (Fig. 19) give a general idea of the manufacture of refined sugar from cane.

The plantations usually arrange their work in such a way that while one crop is being harvested, another is being planted, and a third is actively growing. After the first harvest the old cane plants are usually left in the ground to produce a second crop, termed the "first ratoon" crop. Thereafter a second, a third, or even a fourth ratoon crop may be grown, after which the field is plowed anew and replanted to fresh segments of cane. The visitor, consequently, will seldom see idle sugar land, since it is almost never lying fallow nor being planted to other plants in rotation. The scientific application of fertilizer and of irrigation has made this intensive culture possible, the fields being more productive now than ever before. An average of 1,650 pounds of fertilizer was applied to each acre of cane in 1929. Thus for each ton of sugar produced, seven to eight dollars' worth of fertilizer was used. And for the same amount of sugar, about 4,000 tons of irrigation water was applied to the land. In this way about 150,000 acres of cane were grown in 1929, involving the employment of over 50,000 people. The crop harvested that year amounted to over 900,000 tons and approached \$75,000,000 in value. In terms of sugar this amounts to a little over 3% of the world supply. The United States consumes about seven times the amount of sugar produced in the Hawaiian Islands.

GAUDICHAUD'S GAHNIA

Gaudichaud's gahnia (Plate 16), *Gahnia Gaudichaudii* Steud., is one of the strange members of the *Cyperaceae* or Sedge Family. It is found only on the Islands of Hawaii, Maui and Lanai, but about thirty related kinds exist in various parts of Polynesia, Australia and Southern China. Our plant is particularly common in the dry, open woods adjoining the Chain-of-Craters Road in the Kilauea Section of the Park, and on the upper slopes of Haleakala.

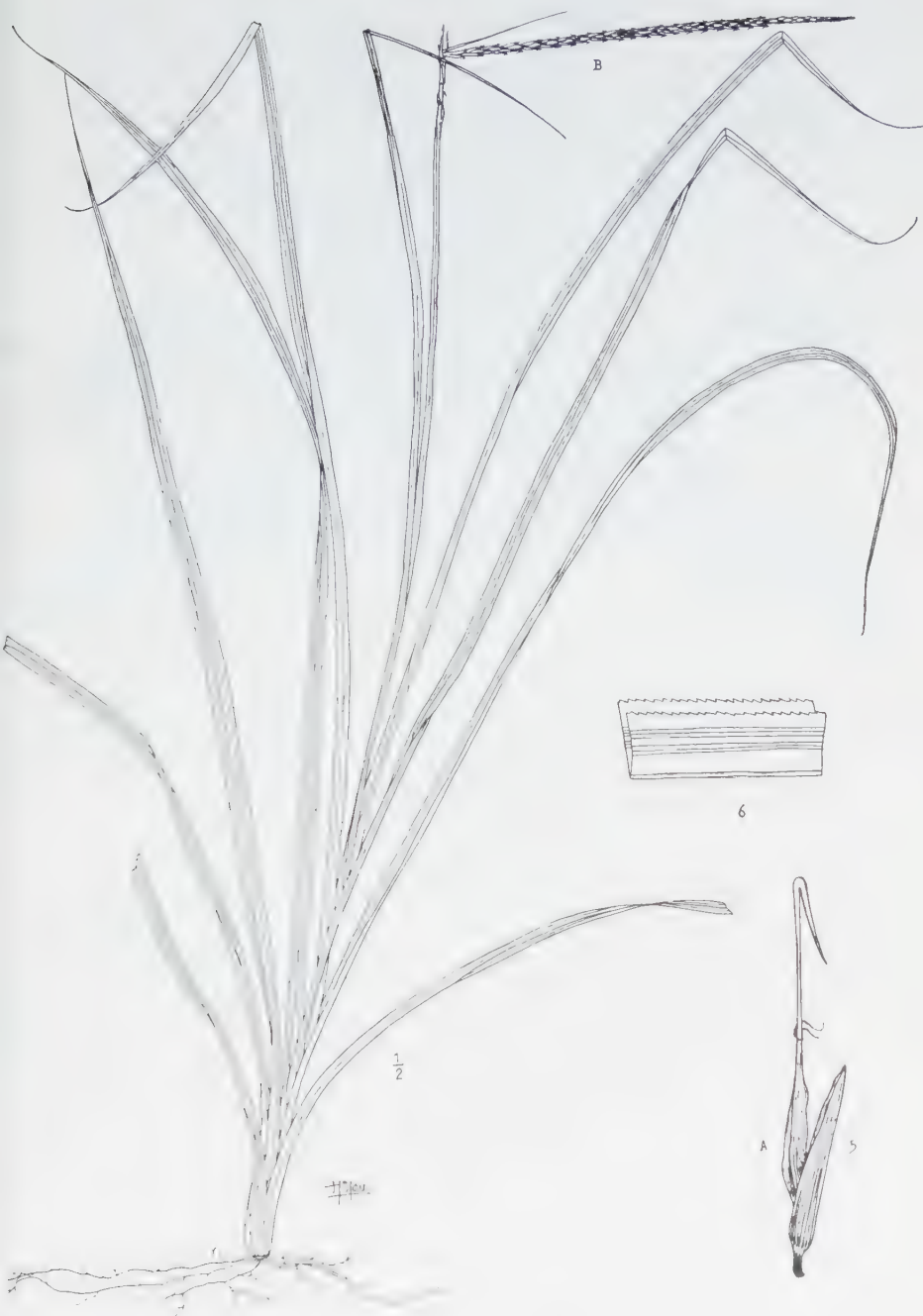


PLATE 17.—*Uncinia*. (Original).

Though not brightly colored, this plant is ornamental because of its intensely black, shiny, seedlike fruits. These hang suspended and dangle often for more than a year from the upper part of the brown, fruiting stalk. The threads that hold them in this inverted position are the wilted stamens. These are firmly attached by their bases to the base of the fruit, while their free ends are curiously held to the plant by the twisting of its drying, scale-like floral envelope.

HAWAIIAN UNCINIA

The Hawaiian uncinia (Plate 17), *Uncinia Lindleyana* Kunth, belongs to the *Cyperaceae* or Sedge Family. It grows usually in the rain forest and may be found on Kauai, Molokai, Maui, Lanai and Hawaii, but not elsewhere. It is rather common in the tree fern forest and in the vicinity of the Thurston Lava Tube in the Kilauea Section of the Park on Hawaii, and along the Olinda Pipe-Line Trail not far from the boundary of the Haleakala Section on Maui. Though superficially resembling a grass, it is an entirely different kind of plant.

Uncinia is related to the many sedges of the continents called *Carex*. Unlike these, however, each of its numerous minute, dry fruits (Plate 17, A) bears a sharply curved hook at the top. This readily catches in the fur or the feathers of animals that scatter the contained seed, thus aiding the plant to become established in regions where it has not grown before.

The ability of the fruit to catch on hair is so annoying that hunting dogs that know the plant from experience try to avoid it. An idea of what the dogs must feel, and of the efficacy of this method of plant dissemination, may be had by drawing the back of one's hand or arm across the ripening fruiting stalk (Plate 17, B) and observing the number of fruits that attach themselves.

COCONUT OR NIU

The coconut palm (Plate 18), the *niu* of the Hawaiians, belongs to the Palm Family, technically termed *Arecaceae* by some students and *Palmae* by others. The tree itself is known botanically as *Cocos nucifera* L. It is the only member in existence belonging to the group *Cocos*, notwithstanding the fact that other palms cultivated in the Islands as ornamentals are locally still known by the same group name.

The question of the origin of the coconut palm has been the



PLATE 18.—Coconut or Niu. (Original)

Habit; coconut fruit entire, longitudinal section when ripe, longitudinal section to show growing seedling with spongy foot filling cavity; spathe enclosing flower cluster; single cluster showing staminate flowers above and pistillate flower below; 3 staminate flowers at different stages of development

cause of much controversy. Some maintain that it is native to tropical America; others, that it is native to the Orient. The belief in the American origin of the coconut seems based primarily on two misconceptions. The first consists in the belief that its closest relatives grew in the New World and that therefore it likewise came from there. The latest investigations, however, disclose that the coconut is not as closely related to American plants as it is to *Jubacopsis caffra* Becc., a palm growing originally in southern Africa. The second error consists in ascribing a statement made by Cieza de Leon, apparently a soldier in Pizarro's army in 1534, as referring to the coconut. De Leon, however, referred to a South American palm allied to *Attalea*. Actually, in addition to de Leon, not a single early writer on America can be found who considered the coconut native to the New World.

The belief in the coconut's origin in the Orient, founded on several kinds of evidence, is more convincing. Its closest relative, as mentioned above, grows wild in Africa. Furthermore, a temple relief (Fig. 20) at Borubudur on Java, dating from the eighth century, depicts a coconut tree in full fruit. Marco Polo, whose travels in the Orient occurred two centuries before the discovery of America by Columbus, definitely refers to "Indian nuts" growing in northern Sumatra, in the Nicobar Island about 200 miles northwest of Sumatra, and along both the eastern and western coasts of southern India. That these were clearly coconuts we know from his following description: "The Indian nuts also grow here, of the size of a man's head, containing an edible substance that is sweet and pleasant to the taste, and white as milk. The cavity of this pulp is filled with a liquor clear as water, cool, and better flavored and more delicate than wine or any other kind of drink whatever." The word copra, the name of the dried meat of the coconut, is derived from the Sanskrit *khorpara* given to the same substance. This also shows that the coconut must have been known in India from very early times.

The best proof of the coconut's original home is given by the robber crab, *Birgus latro* Leach. This crustacean, a highly specialized relative of the hermit crab, becomes about as large as a lobster, has a symmetrical abdomen covered with a series of horny plates, has two huge claws, and has forsaken the sea as its permanent abode but goes there periodically to wet its gills and to reproduce. It spends the greater part of the day in

deep burrows, carpeted with fibers stripped from the husks of coconuts, hollowed out beneath rocks or the roots of trees. At night it comes forth in search of fallen coconuts or, for want of these, actually climbs the trees to pluck the growing ones. To reach the contents of the nut, which is its principal food, the crab first tears away the fiber of the husk covering the three "eyes." At this end it then hammers away with its ponderous claw until a hole is made in the shell, when it extracts the contents. In the Marshall Islands, after most of the walking legs of this crab are amputated to prevent escape, the natives fatten it on coconuts until its abdomen attains the size of a child's head. This is then



FIGURE 20.—Ancient bas-relief on temple wall in Java depicting coconut

roasted and the contents, consisting of a delicious, thick, oily liquid, are eaten with a spoon.

The fact that this crab seems dependent for its normal existence on the coconut and can subsist entirely upon it, virtually precludes the possibility that it evolved to its high degree of specialization where its food plant did not occur. By determining the range of the robber crab one, therefore, arrives at a fairly reliable idea of the area covered by the coconut in early times. The crab is not found in America nor in the Hawaiian Islands, but in such widely scattered regions as the Paumotu and Fanning Islands south of Hawaii, the Liu Kiu Islands between Formosa and Japan, many islands of the Indian Ocean, and even Madagascar. The coconut, before the discovery of the New World, was not only found wherever the crab existed, but also in northern Australia and in isolated regions in Africa. This extensive range of the coconut palm is due probably in part to the fibrous husk that can float the fruit for months in the ocean, and more generally to the Polynesians, or some closely related people, who in prehistoric times carried the fruit both as food and drink on their long voyages to many lands. This may explain why the coconut is known practically throughout its range as *niu* or a variant of this name. Even as far west as Madagascar the vernacular name *wua-niu* for the coconut shows this influence. *Wua*, meaning "new," was obviously a Malagasy word prefixed to that of the invaders who may have brought the coconut with them.

According to tradition, at least the large-fruited type of coconut known as *niu polapola* was brought to the Hawaiian Islands by the early Polynesian navigators from Bolabola, an island not far from Tahiti. Before Captain Cook's coming, the Hawaiians also knew a few other kinds, such as the *niuhiwa* with dark-colored fruit and the *niuilelo* with yellowish fruit. Elsewhere in its range the coconut is known in many other varieties and forms which the natives not only call by distinct names but use for different purposes.

As our islands are almost too cold for the coconut, it grows best on the warmer, leeward side of the Island of Hawaii, the most southerly of the entire group. Here its trunk may be seen standing actually within reach of the ocean spray as well as at higher elevations. In Hawaii National Park it is found only near the seashore south of Kilauea Crater. It is a graceful palm usually becoming sixty to seventy years old though, occasionally, individual trees live a hundred years or longer. The slender trunk rises as

much as a hundred feet from a swollen, inclined base. The trunk is surmounted by a massive crown of leaves, of which the lower have the tendency to droop. These leaves are ten to twenty feet long and bear approximately one hundred leaflets on each side. The strength and elasticity of the trunk bearing such heavy leaves and usually a crop of huge fruits, possibly fifty per year, is remarkable. During the so-called Kona storms that occasionally strike the Islands, the slender trunks lean far toward the ground before the heaviest gusts of wind, only to spring back to their original position after each gust has passed.

From the time the tree is about ten years old it produces clusters of flowers one after another in continuous succession until its death. These are axillary and dependent for most of their nourishment on the leaf immediately below them. If this leaf be cut away, the flower cluster dies. To protect the flowers from injury during their development, the entire cluster is enclosed by a massive, green structure termed the spathe. This finally bursts apart due to the pressure exerted by the enlarging flowers, and liberates them. The entire cluster consists of about thirty-five spreading branches, each thickly beset with several hundred closely pressed staminate, or "male," flowers. Toward the base of the lower branches, only a few pistillate, or "female," flowers develop.

Each "male" flower blooms but for a single day, those toward the top of the cluster opening first. As thousands of these flowers are found in a single cluster, it takes almost a month until all have opened to expose their pollen. Some of this is undoubtedly carried away by insects which have been attracted to the flowers by nectar that exudes from three centrally located glands. Usually several days after all the pollen-bearing flowers of a cluster have bloomed and fallen, the large, globular pistillate, or "female," flowers bloom. This process is obscure, consisting mainly in the secretion of nectar toward their apex and the exposure of tissues receptive to pollen which the wind or some insect may perchance carry to it. Only then can the flower develop into a fruit. Since "female" flowers bloom only after the "males" have decayed, it is utterly impossible for the former to become pollinated with pollen borne in the same cluster. This may be a distinct advantage, as cross-pollination in contrast to self-pollination usually insures the development of more vigorous offspring.

About ten months after the bursting of the spathe, the pistillate flowers have developed into fully grown fruits known as coconuts,

which are completely ripe about five months later. Technically, these are not nuts at all but rather drupes, being characterized by an outer fibrous layer, or "husk", that surrounds an inner stony layer, or "shell." In the Malayan *nawasi* variety, curiously enough, this husk is actually edible.

The shell of all coconuts is marked with three "eyes" near the stem end. These are germinal pores of softer tissue. Through one, which has a plug that lifts out with comparatively little pressure from within, the single seedling forces its way to freedom. The two remaining pores are useless to the plant. They are vestigial structures suggesting that the ancestral coconut palm bore fruit containing three seeds instead of just one.

Within the shell of the coconut lies the white "meat" or solid endosperm which is not part of the embryonic plant, but merely food stored up for its development by the parent. The embryo itself is a minute structure imbedded in the endosperm near the "eye." The liquid, commonly termed "milk," which fills the cavity of the young coconut, is likewise food for the embryo. It is the liquid endosperm.

In falling from the tree, the ponderous seed is well protected by the thick husk from cracking. If it falls in a not too unfavorable locality, germination begins with the enlargement of the embryo and the growth of its first leaf or cotyledon into the cavity surrounded by the solid endosperm. Instead of being a foliar structure, this cotyledon is a white, spongy sphere, termed the haustorium. As this enlarges and presses against the endosperm, the latter disappears. This is because the haustorium first secretes a chemical substance, or enzyme, which dissolves the solid endosperm, whereupon it is readily absorbed and used for food. While this is going on, the stem of the seedling grows out through the "eye" by pushing aside the plug. It then proceeds to bore through the husk to freedom. Meanwhile, roots have grown from the stem, just beyond the "eye," which ramify throughout the husk for nourishment and moisture. Finally the haustorium decays as the parental nourishment is exhausted, the roots penetrate the soil for mineral salts, and the stem unfolds its leaves in the sunshine, where they can synthesize food to maintain life. Thus about ten months after the fruit began to germinate, the young coconut has become established in the soil.

The coconut was one of the most valuable plants to the Hawaiians. Occasionally the trunk was hollowed out and made into

a canoe termed *lOLONIU*. The *pahu* (p. 126), a large drum, was made preferably from the hollowed trunk of the coconut palm or breadfruit tree. If made of palm wood, it had an unusually beautiful grain due to the woody strands, or fibro-vascular bundles, that ramify through the tree.

Though the leaf of the *hala* (p. 47) was chiefly used in plaiting, its flexibility made it unsuitable for fans. Coconut leaflets, being stiffer, were used instead. A broom, or *pulumi niau*, was made of the stiff midribs, termed *niau*, of the leaflets. These were usually tied together at their base. The midribs were also used to string the kernels of *kukui* nuts in the making of torches (p. 195). Because of their stiffness, the midribs were likewise used in the game *panapananiau*. This consisted of bending them in the shape of bows in the hands. Upon releasing them suddenly, they sprang elastically away. The midrib of the coconut or a piece of bamboo was made into a musical instrument, the *niaukani*, which resembled a jew's-harp, one end being placed between the teeth of the player. The entire leaf, with the branch of the *la-i* (p. 97) symbolized high rank. In more recent times, the Hawaiians wove hats of such fine texture from the coconut as to be impervious to rain. The leaflets were first slit in half lengthwise to expose the filiform veins on each side. These were then removed from the green tissue by drawing a needle-shaped piece of bamboo on each side of them through the tissue of the leaflets. After the fibers had been scraped, washed and dried, they were suitable for weaving into the hats. These were just a single fiber in thickness.

The old flower cluster, after it had dried, served as a garden rake.

Every part of the coconut fruit had its uses. The strands of fiber composing the thick husk were used as a strainer. These strands, after being separated, were also braided or twisted into cord called *kaaha*, or *aha*, and made into rope called *lanalana*. These were used generally in tying, for example, the handle, or *au*, to the stone adz, or *koi*. Cracks in canoes were also tied together with this material. Such cord was also made into nets (Figs. 22, 37) for carrying calabashes and other utensils. *Lukca*, a similar cordage, was highly valued for tying the outrigger to the canoe (Fig. 35) because of the belief that it was more durable in sea water than most other fibers. In spite of this quality, however, it was rarely employed in the making of fish nets. The fibers of the *olona* (*Touchardia latifolia* Gaud.) were usually preferred, being

stronger and more pliable. Thick strands of coconut fiber served as a cable for the stone anchors of canoes. Slings, *maa*, were even made from these fibers, or braided from human hair, to be used in warfare for hurling smooth pieces of compact lava with considerable force at the enemy. These missiles were oblong, being about two inches long, and slightly conical at each end to enable them to be thrown with greater accuracy.

Coconut fiber rope was also used in burial ceremonies. These differed markedly according to the rank or profession of the deceased. If a commoner, the upper part of the corpse was raised and the face bent forward to the knees. The hands were then put under the thighs and passed up between the knees. Head, hands and knees were next bound together with rope made of coconut fiber. The corpse was afterwards wrapped in a coarse mat or black sheet of *kapa* (p. 132), or bark cloth, and disposed of within one or two days. It was either buried in a shallow grave in a sitting posture in the garden or even in the house, or secreted at night in a cave. Calabashes of water and *poi* (p. 82), sugar cane (p. 56) and other food were left at the place of interment. The following morning all who had come in contact with the corpse bathed, sat in a row before the door of the house, and were sprinkled with holy water by the priest. After a few prayers had been offered, the ceremony had ended. Sometimes the corpse was embalmed as previously described (p. 27).

It was not uncommon for the devoted husband, wife or friend, as the case might be, to exhume secretly the corpse in order to remove the four leg bones and the skull. These were then washed until clean, wrapped up and enclosed within the pillow to be slept on every night. Instead of the bones, perhaps the palm of the hand would be cut off, salted and dried in the sun and then taken to bed. The palms of Captain Cook were thus prepared after his death, which was sincerely lamented by the good-natured Hawaiians. These relics of the dead were preserved by the devoted until such a time as their love came to an end.

When pigs were offered alive in the *heiau*, or temple, the small ones were carried in the arms of the *kahuna*, or priest, before the idol, and the large ones were led by him before it. In its presence the priest pinched the ears or tail of the animal until it squealed. At the same time he stated which of the devotees had made the offering. Thereafter he made a hole in the ear of the pig, through which he tied a strand of coconut husk. The offering, now sacred

to the god, was liberated until the priest had occasion to make use of it. No matter into what fields it might break to feed, the farmer could do no more than gently drive it away.

Coconut shells, *pu-niu*, were made into drinking cups of two distinct kinds. Those cut in half lengthwise were termed *olo* and reserved for the priests; those cut at right angles to their length were called *apu-niu* and used by others. Parts of small coconuts often tied to wooden handles served as spoons for ladling out food. Shells served as receptacles for fish lines and were even used as musical instruments. The *pu-niu* was a small drum made from the shell, which gave it its name. The end containing the "eyes" was removed and the remainder carefully smoothed and polished. The opening was then tightly covered with the skin of some scaleless fish as, for example, the *kala* (*Acanthurus unicornis* (Forsk.) Shaw). This skin was placed in position while moist and flexible, and fastened to a ring-shaped cushion of *kapa*, the *poaha*, that encircled the opposite end. The natives sometimes used the gum, *pilali*, of the *kukui* tree (p. 198) to fix the drumheads more securely in place. In using the *pu-niu*, it was fastened to the right thigh of the performer. He then beat the instrument with a thong of fiber held in his right hand. In this way his left would be free to manipulate the large drum, *pahu*, that might be standing on his left side. The *puili* was yet another musical instrument. It was made from either a small coconut or a small gourd. Strangely enough, coconuts were forbidden as food to women. This custom was connected with the *kapa* system (p. 109).

The coconut at a certain stage is completely filled with the "milk." This, being slightly sweet and delicately flavored, forms a wholesome, germ-free drink. As the nut matures, the milk loses some of its sweetness and becomes somewhat cloudy. At the same time, the solid endosperm, or "meat," develops. This at first has the consistency of custard and can be eaten with a spoon. With further development, the meat becomes cheeselike and finally firm in texture, in which state it is shipped throughout the world. The Hawaiians not only used the milk and meat of the coconut raw as food, but also used them as ingredients in many cooked dishes, some of which are worthy of trial in Occidental and Oriental homes.

Kulolo was a pudding of coconut and taro. This was made by scraping the meat of a ripe coconut against a rough stone. The juice squeezed from this meat into a calabash was then mixed with

raw, scraped taro. This mixture was next cooked in the *imu* (p. 113), or native oven. A similar pudding, the *paipaice*, was made by substituting breadfruit (p. 129) for the taro. In the case of *poiपाला*, on the other hand, sweet potatoes were used in place of the taro.

The meat of the coconut as well as that of the *kukui* nut (p. 193), both rich in oil, were sometimes chewed and spat by the fishermen over the sea to quiet its ripples in their neighborhood. To oil the hair, pieces of coconut meat were drawn through it or chewed meat rubbed into it. Then the Hawaiian would go swimming to free his hair of the small particles of coconut meat.

Today the coconut industry of the Hawaiian Islands is unimportant. But in the tropical islands to the south and west where the temperature is higher and the labor cheaper, it is of great magnitude. Coir, the fiber of the husk, is made into doormats, brushes and similar articles, and copra, the dried meat, is used as food or as a source of oil for soaps and margarines. Unfortunately, to gain the best quality of coir, the nuts must be harvested when young, a time when their meat dries into the poorest quality of copra. If, on the other hand, a good quality of copra is desired, the nuts must not be harvested until fully ripe. At that time the husk is so old that the coir derived from it is too hard and brittle to be of much value.

In the case of copra, the fully ripe coconuts are preferably gathered once every two months from the trees in the plantations. This is laborious work that cannot well be avoided. In Sumatra, to be sure, monkeys have been taught to climb the trees, twist the nuts from the stem, and throw them to the ground. But this ingenious method is far from commercially practicable. The shelled nuts are cracked open and preferably washed to remove the film of sweet milk which forms a good bed for the growth of injurious bacteria and molds. The pieces are then laid with the inner side to the sun. After the first day, the drying meat has partly curled from the shell and is readily removed for further drying. After about five days, weather permitting, the copra is usually placed in artificial driers for a time. Thereafter it contains little water and 64 to 69 per cent oil, and is ready for shipment to the factory, probably thousands of miles away. There it is grated and freed of the desired oil.

In preparing coconut suitable for the making of candy and cakes, the fresh meat is carefully cleaned and then shredded or

grated. Next it is almost instantaneously dried in a vacuum under heat. In this way it retains its flavor. About three nuts thus prepared produce one pound of dried, shredded coconut.

In some countries, the juice from the purposely cut or bruised flower clusters is collected. While fresh it contains about 15% sugar and is known as toddy. Upon fermentation it becomes palm wine; when this wine is distilled, the product becomes arrack.

TARO OR KALO

The taro is native to the East Indies, but has been carried by the Polynesians in their migrations throughout the Pacific. Thus this plant reached these islands with the early progenitors of the Hawaiian race, to whom it has long been the most important food plant. By the Hawaiians it is called *kalo* while technically, according to the most recent research in nomenclature, it must be known as *Caladium colocasia* (L.) W. F. Wright. The plant belongs to the *Araceae* or Arum Family and hence is a relative of the calla lily and the elephants ear, both grown as ornamentals on the mainland, and of the Jack-in-the-pulpit, which grows wild in the woods of the eastern part of the United States.

The taro (Plate 19) is a typical marsh plant bearing a short, underground stem, or rootstock, which is used as a storage organ for the starch produced by the leaves. Due to the accumulation of this starch, it swells to a great size. The original root decays early in the life of the plant and is replaced by so-called adventitious roots that arise near old leaf scars on the swollen stem. The leaves, borne in an upright cluster, are shaped more or less like an arrowhead. Their stalks are grooved on the inner side and here the young leaves, longitudinally rolled together, lie for protection until it is time for them to expand. When the plant has attained maturity it produces a flower stalk, called the peduncle, which is somewhat shorter than the leaf stalks. Near the apex of the peduncle is a greatly modified leaf, the spathe, which protects the actual flower cluster within. This consists of an erect stem, the spadix, which bears three kinds of flowers. Toward the base lie the pistillate, or "female," flowers, while on the upper part of the spadix lie the staminate, or "male," flowers. Separating the two kinds of functioning flowers, is an area of staminate flowers which have degenerated and therefore never produce pollen.

The taro is conspicuously free from injury by insects and herbivorous animals. This immunity is largely due to the presence of innumerable, minute cells scattered throughout the tissues, each one

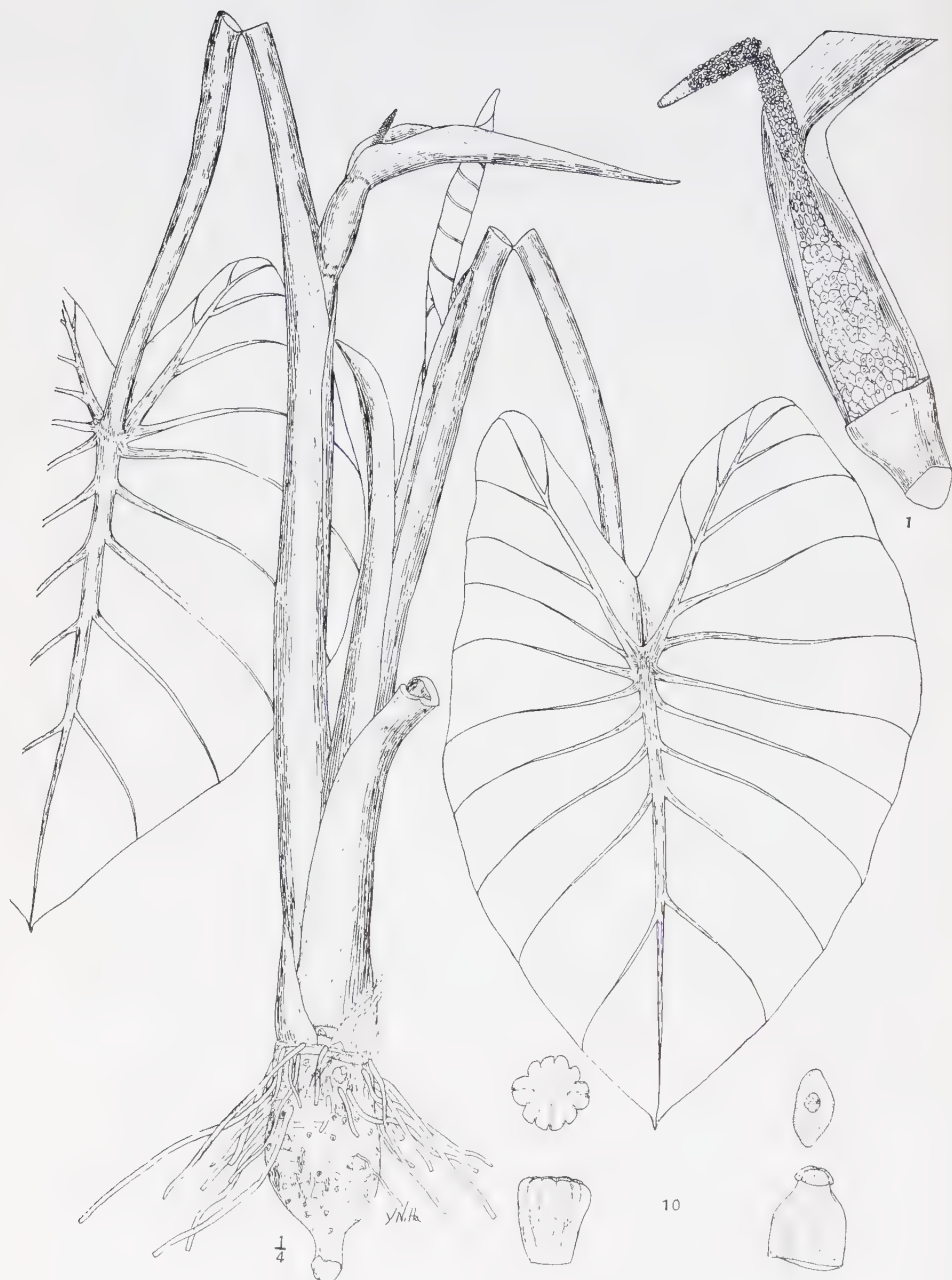


PLATE 19.—Taro or Kalo. (Original).
 Habit, spathe enclosing old spadix with 3 kinds of flowers; male flower in 2 aspects;
 female flower in 2 aspects.

filled with scores of needle-shaped crystals, termed raphides, of calcium oxalate. As soon as the cells are wetted by the saliva or body juices of an insect or a grazing animal attempting to eat the plant, they forcibly expel their crystals. How effective these cells are in preventing the plant from being eaten, may be tested by touching the tongue ever so gently to the cut end of the stem. In chewing part of the raw plant, the lining of mouth and throat will be very painfully irritated. These minute crystals are dissolved in cooking and the plant thus rendered perfectly harmless. The only taro now in the Islands which has so few stinging cells that its rootstock can be eaten raw without pain, is not a native plant, but one introduced from Japan in recent years.

Because the base of the taro is usually completely buried under water in foul mud, it is deprived of oxygen. As access to this element is necessary for the life of all cells, the oxygen must be conducted to the subterranean part of the plant in some way. This is accomplished by means of large canals which pass from the leaf-blade down the stalk to the swollen rootstock. Through here air, rich in oxygen, can readily pass. The leaf-stalks obviously owe their spongy character to these abundant air canals.

The taro, like the banana, has been cultivated by the Polynesians for such an incredibly long time that an untold number of horticultural varieties have originated. In the Hawaiian Islands alone, more than thirty kinds, possessing various noticeable characteristics, were known to the natives by name. They were propagated from crowns cut from the old plants, or from those cut from one-year-old rootstocks arising from the old plants. Most of these kinds of taro require marshy soil for growth. Where this was not available, artificial marshes, or *loi*, were made with the aid of irrigation and the taro planted on mounds built up within a few inches of the water surface. A few kinds will grow in the dry earth of the uplands without special protection, though, to gain a better harvest, it was customary to cover the ground and the stem of the plants with the fronds of ferns like the *sadleria* (p. 40).

As the entire taro plant furnishes food for man, it has been estimated that on one square mile planted to this crop and diligently cultivated, over 15,000 people could subsist for an entire year. The starchy rootstocks, popularly called "taro root," are thoroughly baked in the *imu* (p. 113). Then they are peeled, washed, and pounded (Fig. 22) with a little water into a hard, doughlike paste on a wooden trough called *papakui'ai* or *papalaau* with a stone pestle known as *pohakuku'ai* (Fig. 23). In this state, called *aipaa*,

the taro will keep for several months if properly wrapped in *la-i* (p. 97) leaves. If it was to be used for barter, *aipaa* was commonly put up in twenty or forty pound bundles. This material was usually carried on journeys and then sometimes eaten in that state. More often, however, *aipaa* was allowed to ferment for a few days before being diluted with more water. The resulting gray, gruel-like paste, called *poi*, was then eaten cold and unseasoned. The Hawaiians sometimes sipped it from the rim of the calabash in which it was contained. Most commonly, however, they dipped their index and middle fingers into the *poi*, moved them around in small circles and then, with appropriate manipulations and polite sounds of satisfaction, stuck them into their mouths. The adhering *poi* was then sucked off with the lips. Now *poi* is often made by machinery in a more hygienic way and commonly eaten with a spoon. Today a plate of *poi* can be had at most restaurants.



FIGURE 22.—Hawaiian pounding taro into *poi* with stone pestle, or *pohakukui*, on wooden trough, or *papakui*; four calabashes, or *umcke*, one surrounded with coconut husk fiber rope to facilitate handling; one gourd dish.

The rootstocks of the taro were also baked whole upon hot stones, and in recent times sliced and fried like potatoes. To guard against a possible famine, taro was occasionally baked and dried for keeping over long periods of time. In this state it was called *ao*. *Kulolo* was a pudding made of grated raw taro and the juice expressed from grated coconut meat. This was cooked in a calabash in the *imu*.



(From collections of Warinner, Wiehke & Degener)

FIGURE 23.—*Poi* pounders, or *pohakukui*, the central one coming from the Island of Kauai.

The Hawaiians in the early days were epicures in the eating of dog meat, the neck of the animal being especially esteemed. Such a dish is not revolting when one realizes that certain small dogs were especially raised for this purpose. These were sometimes kept in special kennels and were fed only on vegetables.

particularly the taro, to make their flesh more tender and delicately flavored. For this reason they were commonly called *poi* dogs.

The young leaf blades of the taro are gathered while yet tightly rolled together and enclosed in the groove of the old leaf stalk. Before cooking, the lower epidermis of their midrib is stripped off and discarded. This dish, known as *luau*, which name is also applied to a native feast, is eaten like spinach.

The entire flower cluster of the taro and its stalk was called *puakalo* by the Hawaiians. After the epidermis had been stripped from this stalk and from the lower surface of the midrib of the spathe, the *puakalo* was cooked and eaten. The petioles, or leaf-stalks, called *aihaha* of the taro were likewise freed of their epidermis, cooked and eaten.

Laulau is a special combination of taro and pork. The blades of fresh *la-i* leaves are first flattened out to form a plate or container. Upon this are laid several unrolled *luau*, or taro leaves. Pieces of pork are put on next. Then usually on top of all comes the *puakalo* or the *aihaha*, or a combination of the two. Thereupon the plate of *la-i* leaves is drawn up around the food and securely tied at the top with the ropelike old leaves of the same plant. This bag of leaves (shown in Fig. 27) is then trimmed of superfluous material at the top before it is placed in the *imu*, or oven, usually next to the pig. Such packages of *laulau* are usually only large enough to serve a single person. Cooked in this way, they have a delicious flavor. *Haha* was the term given to the entire taro tops with their tough, old leaves. This material was often steamed and fed to pigs.

Besides being a food, taro had other uses. The cut rootstock in the raw state was touched to bleeding wounds as a styptic. The cut petiole was rubbed on wounds made by the stings of insects. *Aipaa* was used as a poultice on infected sores. As a febrifuge raw taro juice was given to the patient to drink. Because of its irritating quality, it was mixed with sugar cane juice, and with the milk of the coconut and the juice expressed from its meat. Diluted *poi* was used as a paste to glue strips of *kapa* (p. 132) together. Raw taro grated and then cooked was used, as described elsewhere (p. 168), as bait in catching the *opelu*, one of the favorite food fishes. William Ellis, who keenly observed the Hawaiians over a century ago, describes how taro was used in ornamenting their gourd calabashes, some of which had a capacity of four or five gallons. "When the calabash has grown to its full size, they empty it in the usual manner, by placing it in the sun till

the inside is decayed, and may be shaken out. The shell, which remains entire, except the small perforation made at the stalk, for the purpose of discharging its contents, and serving as a mouth to the vessel, is, when the calabash is large, sometimes half an inch thick. In order to stain it, they mix several bruised herbs, principally the stalks and leaves of the arum [taro], and a quantity of dark ferruginous earth, with water, and fill the vessel with it. They then draw with a piece of hard wood or stone on the outside of the calabash, whatever figures they wish to ornament it with. These are various, being either rhomboids, stars, circles, or wave and straight lines, in separate sections, or crossing each other at right angles, generally marked with a great degree of accuracy and taste. After the colouring matter has remained three or four days in the calabashes, they are put into a native oven and baked. When they are taken out, all the parts previously marked appear beautifully dark brown or black, while those places, where the outer skin has not been broken, retain their natural bright yellow colour. The dye is now emptied out, and the calabash dried in the sun; the whole of the outside appears perfectly smooth and shining, while the colours imparted by the above process remain indelible."

Taro was the staple food of the Polynesian just as bread is the staple of the Caucasian, and rice, the staple of the Oriental. An idea of the importance of taro in the diet of the Hawaiian until relatively recent times is shown by the objection many gave a century ago to visiting England—that taro could not be obtained there!

PINEAPPLE OR HALA KAHIKI

The pineapple (Plate 20) is correctly known scientifically as *Ananas comosus* (L.) Merr. It is such a well-known and important member of the *Bromeliaceae* that it has imparted to this entire group the common name of Pineapple Family. The wild Hawaiian plant, unlike most of its relatives, is a large, terrestrial, rather variable herb having a short, massive stem. This bears stiff, linear leaves, sometimes a yard long, in dense spiral arrangement. These are grooved in the center, and armed along their margins with hooked prickles, in that respect resembling the leaves of the *hala* (Plate 13). In the axil of the clasping base of each of these leaves are dormant buds and so-called adventitious roots. The latter, shown after the removal of the lower leaves (Plate 20, at base) are of great value to the plant. Dust and dirt may be blown by the wind upon the leaves to be utterly useless to the plant, but



PLATE 20.—Pineapple or Hala Kahiki. (Original).
 Habit, showing adventitious roots at base of cut stem; seed and seedling; longitudinal
 section of young collective fruit, showing rudimentary seeds in ovary cavity.

when it rains such material washes down the central groove to be retained by the clasping base. Here the adventitious roots are enabled to absorb the water and the soluble constituents of the wind-blown particles, thereby adding raw food to the plant's supply that usually comes direct from the ground.

At flowering time the shortened stem elongates to become several feet high. The upper part enlarges and develops into a variable number of purplish flowers, each borne in the axil of a single degenerate leaf, termed a bract. The remarkable fact about this flower cluster is the firm union of its main stem with the lower part of its axillating bracts and the lower part of its flowers. This is plainly shown in the longitudinal section of the maturing cluster figured, the wilted part of the flowers showing above the free part of each bract. Surmounting all, is the continuation of the stem bearing a crown of small leaves.

With maturity, not only the individual ovaries of the pineapple plant ripen into fruit, bearing hard seeds, but the bracts and the main stem likewise become fragrant and filled with a sweet, acid juice. This stem is the "core" of the pineapple, familiar to everyone. The entire complex structure, known commonly as the pineapple proper, is botanically termed a collective fruit. In the wild state, no doubt, this was an attractive food for various animals. In eating it they must break off the terminal crown of stem and leaves. This crown, practically no matter where it falls, will strike root. Thus, if conditions are favorable, both sexual and asexual reproductive parts of the plant may be disseminated by the same agent at the same time. In the Hawaiian Islands this plant seldom matures seed (Plate 20, at left), probably because a suitable insect to effect pollination is not found here. Nevertheless, rudimentary seed (Plate 20, at right) may always be seen by slicing the fruit.

The pineapple is a native of Brazil whence it has been widely disseminated. It is grown extensively in the open throughout the tropics and subtropics. It was first brought to Europe about 1650, and grown under glass in France and England as early as the latter part of the eighteenth century. As with sugar cane (p. 58), coffee (p. 276) and the pigeon pea (p. 184), it is not known when nor from where the plant was first introduced into these islands. That it was introduced by the Hawaiians is inconceivable as that would presuppose considerable Polynesian intercourse with America. The plant was brought here either directly from the tropics of the New World by the white race or from Tahiti or

some other region to which it had been previously imported from America by the same people. It is even possible that the pineapple, carried as an antiscorbutic, before Captain Cook's discovery of the Islands, was brought here on a Spanish vessel. It is known from Spanish records that three such vessels sailed from Mexico in 1527 for the Moluccas under the command of Don Pedro Alvarado de Saavadra and that two of these never reached their destination. Moreover, in the reign of Keliokaloa, who was born about 1500, a strange vessel, so Hawaiian tradition relates, was wrecked at Keei in the District of Kona. This might readily have been one of Saavadra's small squadron.

Hala kahiki, the Hawaiian name of the pineapple, though it proves the plant's exotic character, is rather an ambiguous phrase. It means either the "Tahiti *hala*" or much more likely the "foreign *hala*." *Kahiki* (k and t in the Hawaiian language being often interchangeable), to be sure, originally meant Tahiti, the island last visited by the Hawaiians around the twelfth century. But as time went on, knowledge of that country became more and more vague to the Hawaiians so that by the eighteenth century *kahiki* meant any foreign country whatever. Whether this foreign country happened to be Tahiti or some other island may never be solved.

According to written records, the first white man to plant the pineapple in the Islands was Don Marin (p. 276). This was done in 1813, though the Hawaiians had been growing the plant in a semi-wild state long before. From William Ellis, who toured the Island of Hawaii in 1823, we know that "oranges, limes, citrons, grapes, pine-apples, papaw-apples, cucumbers, and water melons, have been introduced, and, excepting the pine-apples, thrive well." A year later Andrew Bloxam, naturalist on the Frigate "Blonde", reported that in Honolulu ". . . pineapples and some other fruits are to be had, but not in abundance." Elsewhere he mentions the pineapple as one of the introduced plants. These plants, of which a typical one is pictured on Plate 20, produce rather small but very fragrant, sweet fruit. They may be found near sea level usually as escapes from early cultivation by the Hawaiians. They grow in numbers in rocky places on the Island of Hawaii in Puna, not far from the Park boundary, as well as in Kona, where they to this day receive considerable care from the Hawaiians; they are known from a wet but well-drained forest in Wailau Valley, Island of Molokai; on the Island of Kauai; and probably elsewhere. From these Kona plants Captain John Kidwell, an English horticulturist, established in 1885 the first real

pineapple plantation. This consisted of about five acres located in Manoa Valley, Island of Oahu. The type of pineapple, however, was not the one so extensively planted today for export.

The pineapple for which these islands are well known is a product highly improved by the gardener. One of its ancestors came from the vicinity of Cayenne, French Guiana, and from there was introduced into France in the early days to be grown as a hothouse luxury and curiosity. Some of these French plants were brought to Kew Gardens, England, where they were probably crossed with other South American strains. The greatly improved offspring were later shipped to Queensland, Australia, and to Jamaica for planting on a large scale. In 1886 plants were brought to these islands from Jamaica by Kidwell, and the same kind a few years later from Queensland by E. W. Jordan. These plants, known as the Smooth Cayenne because of the absence of spines on the leaves and because of their country of origin, were grown to a rather limited extent at first. They were sold locally and in San Francisco as fresh fruit only. Due to losses from decay in shipping them, Kidwell and John Emmeluth, a plumber, conceived the idea of canning them. The cans for this purpose were first laboriously made by hand in the Islands. Later cans were imported from the Coast, though the expense was considerable because of their bulk. Now, however, their cost has been greatly reduced by importing the flat sheets of metal and rolling these locally into the shape of cans. Since 1905, the pineapple has risen to be second only to sugar cane in importance as a crop for the Hawaiian Islands. This pineapple has been so improved by man that it is difficult to believe that its ancestor was very similar to the naturalized plant of these islands.

Though thriving in well-drained soil from sea level to an elevation of 1,500 feet, the pineapple in the Hawaiian Islands is grown chiefly above the cane belt, or within it on land naturally too dry for cane and impracticable to irrigate. The plants are propagated in many single rows in the field; or these rows are massed together in twos, threes or even fours. For this purpose, cuttings of several kinds are used, namely suckers, crowns, slips and stumps. Suckers, the young shoots arising from buds in the axils of the lower leaves, are gathered shortly after the fruit from the old plant has been harvested. When planted they may develop ripe pineapples within fifteen to twenty months, the quickest possible time. The crown of the pineapple plant, consisting of the stem and cluster of leaves that surmount the collective

fruit, are saved at the time of canning. After planting they develop their crop rather uniformly, nearly all the plants fruiting at about the same time. Slips, arising from degenerate flower stalks axillary to the main one, are not very different from suckers but mature fruit a little later. Stumps, as the name implies, are the basal parts of the old plants. These were formerly much used to produce an additional supply of plants for setting out in the field. When the suckers, crowns and slips are ready for planting, the rows are covered with a special strip of strong paper (Fig. 24), in which holes are cut at regular intervals. A cutting is then inserted in each hole, the paper not only acting as a mulch to retain the moisture in the soil but also to prevent the growth of weeds in the rows and to raise the soil temperature. This paper is allowed to remain in the field, where it finally decays.

After the first crop has been harvested (Fig. 25), the old plants are deprived of all but two suckers which are left to pro-



(Courtesy R. J. Baker)

FIGURE 24.—Pineapple plants growing in holes made in mulching paper, which is often manufactured from sugar cane refuse.

duce the following harvest. This is spoken of as a ratoon crop. A good field may even yield a second and a third profitable ratoon crop. Finally, about five years after the first planting, the tangled mass of plants is plowed under and the field possibly planted to some rotation crop, such as Para grass (*Panicum barbinode* Trin.) or pigeon peas (p. 184).

In spite of abundant iron in Hawaiian soils, as their rich red



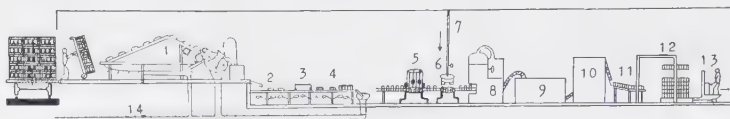
FIGURE 25.—Filipino laborers harvesting pineapple.

color indicates, pineapple roots cannot absorb a sufficient amount of this element for the healthy growth of the plant. Consequently, the plants often sicken as shown by their yellowing leaves. To avoid this condition, it is a common practice to spray such ailing plants with a solution of iron-sulphate. Wherever drops of this liquid fall upon a leaf, the area covered often turns to a healthy green. Then when the rain washes the chemical into the leaf axils, the adventitious roots are enabled to absorb the fertilizer and to transmit it throughout the plant. The iron-sulphate is often made locally by dumping discarded automobiles and scrap iron into vats containing concentrated sulphuric acid. Thus it is not far wrong to state that the iron of cars may be coursing in our veins.

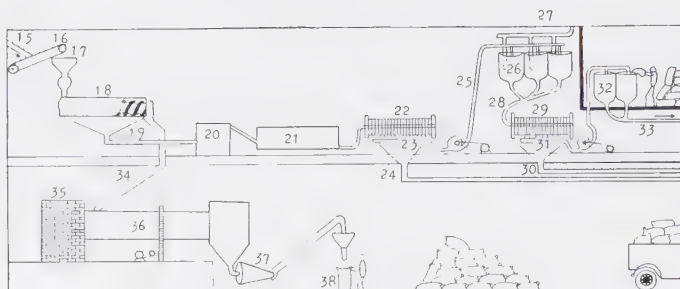
Pineapples were formerly shipped fresh to the mainland, but today nearly all are canned. The diagram (Fig. 26) shows the essential procedure. In 1929 the area planted to pineapple in the Hawaiian Islands comprised 50,000 acres of non-irrigable

land. During that year nine million cases, each containing two dozen cans, were packed. These were valued at approximately \$38,000,000.

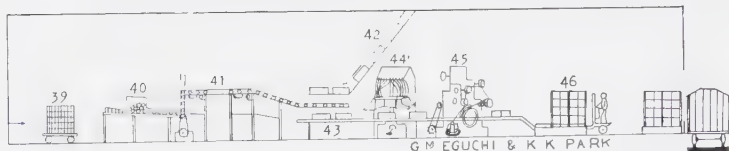
CANNERY



BYPRODUCTS DEPT.



LABELING & SHIPPING DEPT.



(Original)

FIGURE 26.—Diagram of process for deriving canned pineapple, pineapple bran and calcium citrate from fresh pineapple.

1. Ginaca machine for peeling and coring pineapple.
2. Trimming table for further removal of skin.
3. Slicing machine.
4. Packing table for insertion of slices into cans.
5. Vacuum machine for removal of air from pineapple slices.
6. Syruping machine for filling cans with syrup.
7. Pipe conducting cane sugar syrup from mixing tanks at 33.
8. Vacuum seamer for sealing cans.
9. Pressure cooker for sterilization.
10. Cooler.
11. Tray filler.
12. Tray-stacking machine.
13. Truck to cart cans to warehouse for further cooling, for testing and for storage.
14. Conveyor to take skin, core and end slices to Byproducts Department at 15.
15. Wet separator for removal of impurities.
16. Shredder to comminute pineapple.
17. Screw-press for extraction of juice.
18. Pipe for conveyance of juice.
19. Tank for settling of impurities.
20. Juice heater.
21. Filter press for separation of solids from juice.
22. Trough for collection of filtered juice.
23. For disposal of waste.
24. Feed pipe for filtered juice.
25. Liming tanks for removal of acid.
26. Pipe conveying milk of lime.
27. Pipe conveying neutralized juice.
28. Filter press for removal of calcium citrate.
29. Conveyor for removal of calcium citrate, which is used in the making of citric acid.
30. Trough for clarified juice.
31. Tanks for addition of cane sugar.
32. Pipe conducting syrup to Cannery at 7.
33. Wet bran conductor.
34. Furnace.
35. Bran drier.
36. Bran separator for removal of impurities.
37. Bagging machine for brans to be used as stock feed.
38. Tested cans from Warehouse (beyond 13).
39. Can feeder.
40. Labeling machine.
41. Empty boxes from box warehouse.
42. Cans filled into boxes by hand.
43. Box-nailing machine.
44. Box-binding machine.
45. Truck carrying boxed cans of pineapple to freight car for shipment to consumer.
- 46.

DIANELLA OR UKIUKI*

About fifteen kinds of dianella are found in Asia, Australia and Polynesia. All are perennial herbs with short, branching rootstocks, narrow leaves, and usually bluish flowers borne in open clusters. From the character of the individual flower which invariably has its various parts arranged in multiples of three, we can tell that the dianella belong to the *Liliaceae* or Lily Family.

Two kinds of dianella, called *ukiuki* by the Hawaiians, are native to these islands. Only one has been recorded from here before and that has commonly masqueraded under the names of related but foreign kinds. In studying the excellent collections of Hawaiian herbarium specimens at the New York Botanical Garden in 1925, the writer became convinced that the dianella growing in the Hawaiian Islands are not the same as those found elsewhere. The one having a flower cluster usually longer than its leaves and dark, ink-blue berries that are commonly juicy and somewhat oblong is not found within the boundaries of the National Park but on Oahu, West Maui and probably Kauai. This plant is the true *Dianella sandwicensis* correctly described by Hooker and Arnott about one hundred years ago. The other kind (Plate 21) has its flower cluster always shorter than its leaves, and has sky-blue berries. These are depressed-globose in shape. This plant is found growing typically in clumps of bushes on the ash ejected in explosive eruptions in the vicinity of Kilauea, particularly in the Kau Desert, and to a lesser extent in Kaupo Gap within Haleakala Crater. It is interesting that both kinds with their hybrid offspring grow together on a high mountain near Lahaina, West Maui. The lava-inhabiting dianella will be found in the illustrated *Flora Hawaiiensis* properly described, and named after the type of locality in which it habitually grows.

The juice expressed from the berries of the *ukiuki* was formerly used by the Hawaiians as a pale blue dye of considerable permanency for their *kapa* (p. 132) cloth. Whether only one kind of *ukiuki* furnished this dye or both has not been definitely ascertained. The berries of the plant growing near Kilauea, crushed on linen, leave a permanent brownish-yellow stain.

* The collective Hawaiian name for many plants having sedge-like leaves was *ukiuki* or *uki*. The *uki* usually employed as an inner lining for the walls of the ancient Hawaiian grass house was the tall sedge *Pincentia angustifolia* Gaud., which is quite common in the open forest near Kilauea.

PLATE 21.—*Dianella* or Ukiuki. (Original).

TI, LA-I, OR KI

The *la-i* (Plate 22) of the Hawaiians is botanically known as *Taetsia fruticosa* (L.) Merrill, formerly called by the incorrect name of *Cordyline terminalis* (L.) Kunth. Now it is commonly called *ti* or *ki*, a corruption of the Hawaiian word applied to its root. The plant is a member of the *Liliaceae* or Lily Family, as the structure of its flower shows. It is found widely scattered throughout the warmer parts of the Orient and the islands of the Pacific, but its original home is not definitely known. It grows throughout the Hawaiian Islands in great abundance, especially in the wetter, open forests at lower elevations. It is not unlikely that it was introduced here in prehistoric times by the Polynesian progenitors of the Hawaiian race. Because of its ease of cultivation and its variability, it has been one of the favorite plants of the horticulturist, who has produced many ornamental forms bearing leaves of distinctive shape and color. Some have purple, pink, yellowish or white-spotted leaves, while others exhibit various beautiful metallic hues. Such plants are commonly planted in gardens throughout warm and tropical countries, or within doors in colder regions. They are usually called *dracena* by the layman in spite of the fact that the plants do not belong to the botanical group *Dracaena*. To be sure, of the latter at least two kinds are native to the Islands, the one growing on West Oahu being first described in the *Flora Hawaiiensis*. These plants were called *halapepe* by the Hawaiians, meaning "baby *hala*," a name appropriate because of their resemblance to the screwpine (p. 43).

The *la-i* is a simple or sparingly branched plant, three to ten or more feet high, arising from a thickened root. Its yellowish stem bears a terminal cluster of spirally arranged leaves. As each of these falls to be replaced by younger ones, its former place of attachment to the stem remains as a circular scar. Each leaf consists of a grooved petiole or stalk, and a shiny, oblong blade. When the plant flowers in spring, it produces a drooping, branched flower-cluster at least one foot long. This bears numerous, closely-set, white buds tinged with pale purple. Each is about half an inch in length. As the flower blooms, its six perianth lobes curl back to expose six spreading, yellow stamens and a single, white, erect pistil. Only very rarely does a flower mature into a spherical berry a quarter of an inch in diameter. This is yellow at first but changes to bright red when fully ripe.



PLATE 22. -Ti, La-I, or Ki. (Original).

The *la-i* was of great value to the Hawaiians up to a few generations ago. Its leaves, which go by the same Hawaiian name as the entire plant, were sometimes used in thatching their houses (p. 269), or shredded up to form a cool, serviceable *pau* (Fig. 16 and p. 140), or skirt, reaching from the waist usually half way to the knees. The main disadvantage in wearing this garment, however, was that it lacked permanence. Upon wilting and shrinking, it had to be replaced. The leaves were also used extensively for wrapping *aipaa* or hard *poi* (p. 82), fish, fruits, *limu* or edible seaweed and, in fact, almost anything that required a paper-like support. The leaves of the plant were extensively used in cooking in the *imu* (p. 114), the food often being wrapped in them so that it should retain most of its flavor and remain clean. They were used in place of plates and sometimes folded into convenient drinking cups. By rolling up a strip of the fresh leaf about one inch wide and six inches long, a rude musical instrument, called *pu* or *pulai*, resulted. This, when held compressed between the lips and blown into, produced a flute-like tone. In former times this was occasionally used to accompany impromptu *hula* dances (p. 53).

The *la-i* was considered sacred to Lono, the god for whom Captain Cook was mistaken by the Hawaiians. Enclosures dedicated to that god were therefore thatched with this plant. As a flag of truce in war times a branch of the *la-i* or a young banana plant were sent to the enemy. The *la-i*, as well as the coconut, was a symbol of high rank or divine power. It was therefore often worn by the *kahuna*, or priest, around the neck. It was considered a charm against evil spirits. Because of the superstition that those partaking of cooked *opelu* would otherwise suffer from a rash, some *la-i* leaves were customarily tied around the tail of that fish.

The surplus amount of food which the *la-i* plant manufactures in its leaves is stored in its thickened root, correctly called *ki*, not in the form of starch, but as sugar. This amount being considerable, the root was often baked and then eaten. It has a taste not unlike that of molasses candy.

Before the coming of the white man, the Hawaiians brewed beverages of low alcoholic content from the *ki*, sweet potato, or sugar cane. Before 1800, however, they were taught by some convicts from Botany Bay, Australia, to distill a strong intoxicant from the *ki*. The root was first baked in the ground and then

macerated in a canoe. After standing for five or six days, in spite of the abundance of insects, it was distilled in the iron caldrons of the whalers in which whale oil had been tried from the blubber. A gun barrel was attached to this to conduct the vapor and to reduce it to a smoky whiskey. As the bottom of a calabash was known as *okole* to the Hawaiians and iron as *hao*, the crude still and its products were named *okolehao*. The use of this strong liquor and the introduction of diseases foreign to these islands before their discovery by the white man have been potent factors in reducing the native population. When Kamehameha forsook drinking *awa* (p. 122) for alcoholic liquors, many of the Hawaiians followed suit. Kamehameha, noticing the ill effects of this habit, later wisely abstained.

Women before marriage wore the hair long. After marriage and the birth of their first child, it was customary for them to have their hair cut short over the back of the head. Over the forehead it was cut so as to enable them to dress it into a tuft by smearing it with the juice of the root of the *la-i* mixed with *pilali*, the gum obtained from the *kukui* (p. 198). This same juice was also mixed with lime and then, by some fashionable natives, rubbed into the hair. This dressing, called *hawena*, gave it a shiny luster and bleached it gray or even white.

La-i leaves were used by the Hawaiians when suffering from headache. The midrib and stalk were removed and the remaining part of the leaf placed in cold water. This was then dried and tied around the head to cool it. As soon as the bandage became heated, freshly cooled leaves were substituted. Such leaves were also spread under the backs of bedridden invalids to relieve soreness.

Where smooth, grass-covered slopes abounded, the Hawaiian children often amused themselves by sliding down hill sitting on a few leafy *la-i*, holding the stems between their legs.

ASTELIA OR PAINIU

The astelia, or *painiu* of the Hawaiians, belongs to the *Liliaceae* or Lily Family. There are several different kinds and varieties. These are so perplexingly variable that botanists neither agree as to the number existing in these islands nor as to the scientific name by which the more common ones should pass. The plant growing in the vicinity of Kilauea may be called provisionally *Astelia veratroides* Gaud., while a different one growing on



PLATE 23.—*Astelia* or *Painiū*. (Original)

Haleakala and here illustrated (Plate 23) should go by another name.

Astelia grow at higher elevations where rainfall is abundant, either on the ground or more commonly on the moss-covered trunks of trees. Plants of this type, that merely perch on others but do not rob them of food, are termed epiphytes; while plants like the mistletoe (p. 148), that actually live upon the juices of their host, are called parasites.

The requirements for epiphytic existence are more severe than for existence on the ground. A plant growing upon a tree trunk lacks the constant supply of moisture that a terrestrial plant receives from the soil. It must therefore either become dormant during dry seasons or store up as much moisture as possible in its tissues during rainy days to be used for its life processes during periods of drought. The *astelia* is particularly well fitted to survive these dry periods. Its leaves are covered with a white, silky layer of wax. This greatly restricts the amount of water given off by evaporation during sunny days and thus conserves the hard-won water supply within the plant. As an additional precaution, the leaves are so closely pressed together at the base that they catch and retain rain water as in a cup. In the rain forest on Molokai and presumably also within the boundaries of the Park, the water supply in the leaf axils is so constant that the native damsel fly, a relative of the dragon fly, lays its eggs in them as a convenient home for its aquatic larvae.

The small greenish flowers of the *painiu* are not in themselves beautiful, but the entire plant with its silvery leaves and white, hairy flower stalk produces a very ornamental effect. It is exceedingly attractive in late summer when bearing clusters of bright orange berries. These are easily seen and then eaten by birds which deposit the swallowed seeds on branches of trees in their droppings. Without their aid, this plant always would be terrestrial.

The Hawaiians occasionally stripped the silvery epidermis, or skin, from the leaves of the *painiu*. This material, alternating with some fern, was then interwoven with various kinds of flowers into a garland, or wreath, called *lei painiu*. The silky epidermis, sparkling in the sun like glass, would give a beautiful effect to the whole.



PLATE 24.—*Sisyrinchium* or Maulaili. (Original).

HAWAIIAN SISYRINCHIUM OR MAULAILI

The Hawaiian sisyrrinchium (Plate 24), the *maulaili* of the natives, is botanically known as *Sisyrrinchium acre* Mann. It is peculiar to the Island of Hawaii and to East Maui. It may be found in boggy ground near the Hilo entrance to the Kilauea Section of the Park and along the trail leading up the slope to the Rest House on the rim of Haleakala Crater.

About one hundred fifty kinds of sisyrrinchium are known, almost all native to America. Because of their short rootstocks and their linear leaves, they are often mistaken for one of the grasses among which they commonly grow. So, when they produce their ephemeral flowers which are usually blue in color, the layman calls these plants blue-eyed grasses. A study of the flower, however, will at once prove that these plants are not grasses, but belong to the *Iridaceae* or Iris Family. As the Hawaiian plant bears yellow flowers, it cannot very well be given the vernacular name used on the continent. It had better be known as the Hawaiian sisyrrinchium or by the native name which, when separated into syllables to aid in its pronunciation, reads mau-ula-ili.

The earliest Polynesians that populated the Hawaiian Islands possessed a comparatively primitive native civilization. But around the eleventh and twelfth centuries considerable waves of migration from Tahiti to the Hawaiian Islands occurred, the voyagers navigating the ocean in double canoes (p. 178) of enormous size, carrying upward of a hundred men and women with provisions, water, and objects deemed worthy of introduction into a new country. The intermarriage of these newcomers with the older stock already living in the Islands was the beginning of a Hawaiian Renaissance—*heiau* or elaborate temples were built, religious ideas were revised, the *hula* (p. 53) was taught, the *kapu* (p. 109) or "taboo" system with its many objectionable features was instituted, a more rigid caste system was evolved in which the invaders ultimately became the nobles and priests, and tattooing was practiced. The Hawaiian sisyrrinchium was one of the plants employed in this ornamentation.

Tattoo marks were usually made with an instrument called *moli*. This consisted mostly of a flattened piece of *kaula* (p. 204) wood, about a quarter of an inch wide, in which either shark's teeth, sharp shells or fish bones had been partly imbedded in a definite design. The *moli*, first dipped in a dye, was placed upon the body surface that was to be ornamented, or on the tongue in case of

mourning, and then quickly struck with a small rod, the sharp points piercing the flesh and at the same time carrying the coloring matter under the skin. The wounds, upon healing, then showed a permanent stain. One of these dyes was made from the juice of the *mauulaili* mixed with that of the purple fruit of the Hawaiian pokeberry (*Phytolacca brachystachys* Moq.). This method of gaining a tattoo was very painful, but its advantage was in the permanency of the marks.

The *mauulaili* was also used in painless tattooing, especially by women. The marks in this case lasted only for about a year. The leaves were split lengthwise and the torn surface laid upon the skin in the desired pattern. A tight bandage was then applied and within an hour a reddish brown mark appeared which could neither be washed nor rubbed off. The *hula* dancers, for example, would tie the leaves against their wrists and ankles so as to form certain patterns. If these were later considered sufficiently ornamental, a permanent tattoo with the *moli* would be cut into the skin.

In the early days, travelers would often prove to their friends at home that they had visited the Crater of Kilauea by tattooing each side of their mouths with the *mauulaili*. As this plant was known to grow in the vicinity of the crater, such a mark would attest the truth of their story.

Although with the coming of the white man members of the Hawaiian race gave up this custom of marking their skins, some "tattoo artists" supplied with electrically propelled needles and synthetic inks still drive a brisk trade here in depicting mermaids and compasses on the fair arms and chests of numerous *haole*, or strangers.

TRITONIA

In driving from Hilo to Kilauea, the visitor may see long, slender wands of brilliant orange flowers giving color to the roadside. This is the tritonía (Plate 25), often incorrectly called montbretia, introduced into these islands as an ornamental probably before 1900. It has unfortunately escaped from cultivation and now grows naturalized in moist meadows and similar places in various districts on the Island of Hawaii as well as at the head of Waimea Canyon on the Island of Kauai. This plant has already become so noxious a weed in pastures and cane fields that it should be eradicated, in spite of its beauty, wherever possible.

The tritonía is not a direct product of nature but of man. It is the result of crossing two African plants belonging to the *Iridaceae*



PLATE 25.—Tritonia. (Original).

or Iris Family. The one is botanically known as *Tritonia Pottsii* Benth. & Hook., while the other is *Crocasmia aurea* Planch. The resultant hybrid, first blooming in 1880 in France, where it was named X *Tritonia crocosmaeflora* Lemoine, is almost invariably sterile and unable to produce seed. This inability of hybrids to reproduce when their parents are very distantly related is common to both plants and animals. Among the latter, the mule, a sterile cross between the donkey and the mare, is a well-known example.

The tritonia, as the illustration shows, bears long, slender, upright leaves. These are attached to an extremely short, thick stem, called a corm, that somewhat resembles an onion bulb in shape. From this, subterranean branches arise to radiate in all directions and to give rise at their ends to a second series of corms and upright leaves. This type of growth continues indefinitely, the slender underground branches between the corms finally dying and isolating the newer growth into separate plants distinct from the old. Thus a colony of tritonia can rapidly spread over a field even though no seed are produced.

BANANA OR MAIA

The banana, the *maia* of the Hawaiians, is the best known member of the *Musaccac* or Banana Family. It is strictly native to the tropics of the Old World, where it has been cultivated from pre-historic times. The army of Alexander the Great found it planted on a large scale in the Indus Valley as early as 327 B. C. It was undoubtedly spread throughout the Pacific by the Polynesian and related races. Probably influenced by primitive cultivation and selection, a few distinct kinds of banana have developed into hundreds of varieties and forms, most of which have lost the ability to produce seed.

The banana is a really remarkable plant. It is not a tree, but a giant herb which has no aerial stem for the greater part of its life. The true stem is so contracted that it consists of a massive subterranean structure not unlike that found in the taro plant (p. 79). From here leaves arise in concentric arrangement, the youngest developing in the center, as in the onion. With the formation of such central leaves, the older ones are forced apart to form, in cross section view, a series of crescents (Plate 26, at right).

The ensheathing stalks of the leaves of the banana form the stem-like structure commonly mistaken for a true tree trunk. The

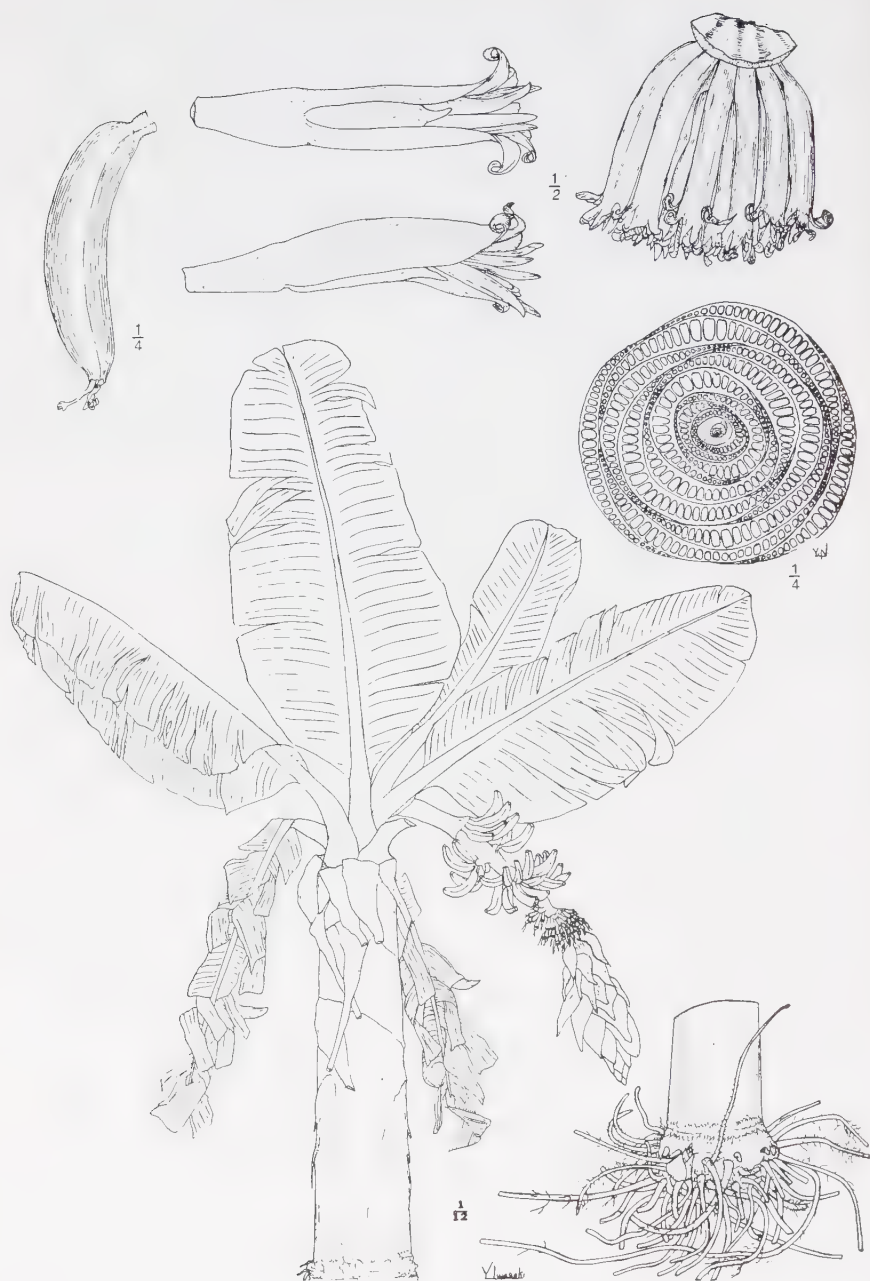


PLATE 26.—Banana or Maia. (Original).

Chinese kind, showing habit, fruit, flowers, cross-section of false stem and true stem at base.

upper part of each stalk does not clasp the others but diverges somewhat to expose the enormous, oblong, terminal blade to sunlight and air. It must take considerable force to enable the young leaf to push its way from near the surface of the ground through the older encircling leaves. In order to do so, its blade is tightly coiled into a compact cylinder which lies in a groove found in the midrib of the leaf next in age.

To facilitate the passage of the young leaf into the air and to prevent its premature uncoiling and possibly the entrance of rain water, its apex consists of a long, filiform point. This seems to have no other function, tearing and dying as soon as the blade unfolds. Mucilage cells, and possibly a bloom consisting of a wax-like powder, act as lubricants to enable the young leaf to slip beyond the old.

The blade of the leaf has prominent veins running at right angles to its length but lacks veins running lengthwise. For this reason it easily tears into segments with the wind. When not excessive, this apparent mutilation seems to be harmless to the plant. Another feature of interest in the leaf blade is the presence of a pulvinus, or cushion, along each side of the midrib. This acts as a hinge. In dry or hot weather, it enables the two halves of the blade to collapse downward, and even to touch each other. Their under sides, being covered with countless microscopic pores from which moisture escapes, are thus protected from undue loss of water by evaporation. If the water supply for the plant is sufficient and the heat moderate, however, the blade is exposed in a flat sheet to the sun and the under surface is bared to the breeze.

As the plant approaches maturity, the contracted basal stem begins to lengthen and to push its way through the center of the column made by the sheathing leaf stalks. It terminates in an oblong flower cluster. This stands erect and matures fruit in that position in a few kinds of banana, for example in the *fei* (*Musa fehi* Vieill.) which was introduced into these islands from the South Seas early in the nineteenth century. Ordinarily, however, this flower cluster bends over as Plate 26 shows.

Preparatory to flowering, a shallow, cup-shaped structure, usually of a brownish red, curls back. This originated in generations past by the union of several leaves, one standing under each flower. Situated before one of these structures, which might be called a collective bract, one will observe two horizontal rows of flowers. These have well-developed pistils, or "female" organs,

and degenerated stamens, or "male" organs. They secrete an abundance of nectar which in some kinds of banana is jelly-like and considered a delicacy by the Hawaiians. Such nectar attracts insects and birds which may, in their visits from flower to flower, cause pollination and insure the setting of seed. Due, however, to long-continued cultivation, as previously mentioned, fruits mostly develop without pollination and usually fail to mature seed.

Below the first two rows of pistillate flowers a second foliar structure is found, protecting a second pair of rows of pistillate flowers. This arrangement continues without interruption to the apex, the only change being in the character of the flowers. Those toward the middle of the cluster become perfect, namely bear both pistils, or "female" organs, and stamens, or "male" organs. The very apex, on the contrary, bears staminate flowers which, of course, lack functioning pistils.

The pistillate and often the perfect flowers develop into bananas, the crop maturing about a year after the plant has first appeared above the soil. The entire fruiting cluster forms the bunch of bananas, while each pair of rows of bananas, that has been protected by a single collective bract, is commercially termed a "hand." After the fruit has ripened, the plant dies. Suckers, however, arise from its base to become isolated into new individual plants later on.

The plants vary in height from about eight feet, in the Chinese banana (*Musa Cavendishii* Lamb.) here shown, to thirty-five feet, in the *fei* or *bolabola* banana. In most cases the collective bracts covering the staminate flowers fall, but in the Chinese kind the terminal bracts are persistent. The bunches commonly bear five to nine hands, totalling about 250 fruits. In the "king of thousands," a Malayan banana, the bunch has been known to grow to a length of seven feet and to bear 2,000 fruits. At the other extreme comes the *lubang* (*Musa corniculata* Lour.) of Cochin China, in which the entire bunch commonly consists of just a single banana not unlike a large cucumber in appearance. The skin of the fruit in the different kinds varies from yellow to red or even green when ripe, while the pulp varies from yellow, pink, salmon to almost white. In consistency the pulp ranges from soft to firm. In many cases the fruits can be eaten raw, and such plants are called bananas in the West Indies. Those that are best suited for cooking, like most of the feral Hawaiian fruits, are generally known as plantains in the same region. In the tropics of the Old World, on

the contrary, both types of plant are known as plantain. All bananas show dark spots, the abortive seeds, in the pulp; or, in very rare cases, have viable seed. These are hard, more or less round, and often angular.

The banana grows best in sunny mountain gorges and swampy yet well-drained areas below an elevation of about 4,000 feet. It is found throughout the Hawaiian Islands, especially on the slopes of Haleakala. Its occurrence in such isolated places is explained by the fact that the Hawaiians purposely planted the bananas in the mountains and that suckers from these plants were occasionally washed to lower elevations by freshets and there produced new clumps of plants. Seventy kinds of bananas were known to the Hawaiians living in the Kona District of the Island of Hawaii. When one considers that bananas were grown on the other islands of the group as well, it is quite possible that several hundred forms were known to the natives in the early days. Since the introduction of the Chinese banana by way of Tahiti in 1855, many of these interesting though less productive Hawaiian kinds have become extinct.

Besides the value of its fruit as food, either raw or cooked, the banana plant was used by the Hawaiians in other ways. The false trunks, being about 80 per cent water, were mashed and commonly placed in the *imu* (p. 113), or native oven, to generate steam for the cooking of food. A young plant was used as a flag of truce in war.

The banana was often used in sacrifice, daily offerings to the spirits of the dead being made of the fruit as well as of certain kinds of fish and of *awa* (p. 122). The banana, and in fact almost anything appropriate to give to the gods, was *kapu* for women to eat. Among these objects may be listed pork, turtle, coconut, bread-fruit if from trees growing in plantations, and certain fish, like the *ulua*, shark, *humu* and *hihimanu* or sting-ray.

The *kapu* system, characteristic of the Polynesians and probably most fully developed by the Hawaiians, was a religious rather than a civil regulation to which even the king was subject. It influenced the daily life of the people with complicated and often useless restrictions whose violation was usually punished with death. Some *kapu* were permanent and well understood by all, while others were temporary and erratic. Permanent *kapu* were usually those relating to idols, temples, chiefs, and customs in eating and in housekeeping (p. 268). The special or temporary *kapu*

were imposed by the king or the *kahuna* for some definite reason, such as conserving food that was getting scarce and protecting fish during spawning time, or merely for a whim.

Women were prohibited from eating with the men excepting under special dispensations, as at the *hula* school feast (p. 56). They were forbidden to eat food cooked in the same oven as was that of the men unless the oven were of special construction. To save labor, men of the lower classes often formed what might be considered eating clubs from which their wives were excluded. The regulation about eating was so extreme that a daughter from the time of her birth could not be fed any food that had been kept in the father's dish or cooked at his fire; and the son, after weaning, was fed with his father's food, and, as soon as he was able, ate his meals with his father. His mother, at the same time, was not only obliged to eat in an outbuilding, but was interdicted from even tasting the kind of food that he ate. Infringement of these regulations was a capital offense.

Death was the penalty for the slightest breach of etiquette established by *kapu* in the neighborhood of the king or the high chief. It meant death for a common man to remain standing at the mention of the king's name in song, or when his food, drinking-water or clothing was carried past; to put on any article of clothing belonging to him; to enter his enclosure without permission; or even to cross his shadow or that of his house. If he entered the presence of the king, he crawled to him prone on the ground and left him in the same manner. The king's head was considered especially sacred. For anyone to touch it or to occupy a position above it was regarded as treason. So, even years after the coming of Captain Cook, no subject dared appear on the deck of a vessel when the king was in the cabin below.

There were times during the *kapu* period when no one could sail a canoe, nor be seen abroad, nor bathe. No domestic animals could cry for fear of breaking the *kapu* and rendering it worthless. Chickens were then usually confined in a covered calabash to keep them quiet. If a disturbance occurred while such a *kapu* was in effect, the offender was killed by strangulation or by being beaten with a club or stone, and usually offered as a sacrifice in the *heiau* (p. 233). So oppressive and rigorous was this system that the otherwise comparatively happy existence of the people often suddenly changed to a life of fear and misery.

In 1818 the last capital punishment for the breaking of a *kapu*

was inflicted, this occurring at the City of Refuge, or *puuhonua*, at Honaunau, Island of Hawaii. At that time one person was killed for putting on a chief's loin cloth; another, for eating something which had been *kapu*; and a third, for leaving a house under *kapu* and entering one which was free. Some years previous to this infliction of punishment at Honaunau, at the same place two young girls of the highest rank, Keoua and Kapiolani, the latter being the chiefess after whom a Honolulu park has been named and who defied the goddess Pélé (p. 244), stole into the sea with a banana and there ate it in the belief that they would escape observation. A *kahuna*, however, detected them in the act of committing this crime. Due to their high rank, the girls were absolved of the offense. Instead, their tutor was held to blame and drowned to appease the insulted deities.

Of this entire complex system the only relic that has survived to the present day may be seen in wayside warnings. Instead of reading "No Trespassing," they usually read *Kapu*.

HAWAIIAN GINGER OR AWAPUHI

The Hawaiian ginger (Plate 27), or *awapuhi* of the natives, is botanically known as *Zingiber zerumbet* (L.) Rosc. It is a member of the *Zingiberaceae* or Ginger Family. The plant is native to the Hawaiian Islands as well as to most tropical regions between here and India. It may be seen growing at lower elevations in the woods adjoining the road that leads from Hilo to Kilauea.

The *awapuhi* has a thick, prostrate rootstock, called rhizome, from which two distinct kinds of upright stems arise. The one reaches a height of one to rarely three feet and bears about a dozen leaves arranged in two vertical rows. Exposed to light and air, these manufacture various substances necessary for the existence of the plant, aided by the roots that have absorbed water and minerals from the soil. The surplus supply is then translocated, or carried, to the swelling rhizome where it is stored for future use. Toward late summer, the second very different type of stem develops. It is much shorter and appears club-shaped because of a terminal cluster of modified, often reddish leaves termed bracts. These are scale-like, concave, and so closely arranged on the stem that their margins overlap. A delicate bud is borne in the axil of each of these bracts to be protected in an unusual way from all possible insect injury. Glands within secrete a copious supply of clear, watery slime that covers the buds and completely



PLATE 27.—Hawaiian Ginger or Awapuhi. (Original).

fills each cup-shaped scale, making it impossible for insects to gain entrance here without great danger of drowning. The buds finally develop into inconspicuous, pale yellow flowers that last less than a day.

The pungent rhizome of the *awapuhi* was powdered by the Hawaiians to be used as a perfume for their *kapa* (p. 132), while the swollen ends of the club-shaped stems are gathered even today and squeezed over the hair to liberate their fluid in preparation for a shampoo. This liquid in former times was not washed out of the hair but allowed to dry.

The leaves of the ginger were used to flavor meat. If a pig, for example, were to be cooked, the Hawaiian men in the early days dug a circular pit about four feet in diameter, or an oval one about four feet long, two feet wide and one to three feet deep. This was called the *imu* (Fig. 27). It was lined with stones, and then dry grass or leaves and wood suitable for making a fire were placed within. Over this material more stones were laid so that the entire mass projected above the surface of the soil. Only certain kinds of porous stones were used for this, however, as others might crack or explode into fragments with the heat, possibly injuring the people near at hand. Around the rim of the *imu*, a single row of large stones was placed. Then the fire was kindled as described on page 215. When most of the wood had burned away and the smaller stones were red hot, the remaining pieces of wood and smoldering embers were carefully removed, as their smoke might impart a disagreeable flavor to the cooking meat. The ashes, on the contrary, were merely brushed aside with a branch or coconut leaf. Then the slaughtered pig was dragged back and forth over the red hot stones to singe away its bristles, the large stones around the rim of the *imu* preventing the pig from touching the soil and preventing the hot stones from being scattered. After that, the pig was scraped free from dirt and any remaining bristles with a special lava stone, called *olai*, which can be gathered along the shore. Such stones have congealed from their molten state while containing numerous bubbles of gas. Due to the wearing action of the waves, these stones usually are more or less rounded. The petrified bubbles, partly worn away on one side, give the stone a pock-marked surface, each depression being bounded with sharp edges. After the cleaning, the pig was eviscerated. The heart, liver, lungs, kidneys, pancreas and alimentary canal were laid aside, the latter to be carefully cleaned by passing *la-i* (p. 95) leaves

through it and turning it inside out. Salt was sprinkled within the pig and some water added to form a gravy. Then the largest stones were thrust out of the way. Thereafter, the Hawaiians with bare hands, wetted in a calabash of water by their side, would quickly place the red hot stones into the body cavity of the pig, stuff several through the mouth into the throat, and place large ones in the gashes cut into the side of the pig under each leg. Then if fresh ginger leaves were at hand, these were thickly laid in a slight depression in the mass of red hot stones. If ginger could not be had, *la-i* or banana leaves or the mashed "trunk" (p. 105) of the banana were employed. The pig was then laid upon the leaves. To one side of the body a calabash, usually of *kaula* (p. 204) wood, containing the edible organs and the cleaned entrails was



FIGURE 27.—Hawaiians wearing the *malo*, or loin cloth, preparing the *imu*, or earth oven, for the slaughtered pig, in which red hot stones have been placed, and for the *lulau* wrapped in *la-i* leaves.

placed. The leaves were sprinkled with water and then covered with a large sheet of *kapa* to keep them clean. Thereupon everything received a layer of earth about a foot deep, forming a slight mound. The water and plant juices, gradually coming in contact with the hot stones, turned to steam. This and the radiating heat of the stones completely cooked the pig within two to three hours. To hasten cooking, the Hawaiians sometimes had a bamboo, with its inner partitions broken, leading from the hot stones to the surface. Through this novel pipe water was then poured which, upon reaching the stones, turned to steam. The blanket of earth which kept the steam from escaping was at length carefully removed with the *kapa*. The leaves that produced the steam were thrown aside, as well as the rocks within the roast. The latter was then placed on



(Courtesy R. I. Baker)

FIGURE 28.—Hawaiian lei woman wearing holoku.



PLATE 28.—Common Gingerlily. (Original).
 Habit; single flower; rhizome or true stem; capsule, seen from side, exposing its crimson seed; single seed; capsule seen from top, exposing its seed.

a large, wooden platter, cut into pieces with the serrate edge of a split piece of bamboo, and served. The *kapa* and stones were saved to be used again in the same *imu*. This method of preparing food took the place of cooking in pots and pans, utensils which the Hawaiians lacked because of the absence of clay suitable for pottery, and metals in a form available for smelting.

COMMON GINGERLILY

The common gingerlily (Plate 28), *Hedychium coronarium* Koenig, is not native to the Hawaiian Islands, but to the Orient. It was purposely brought here over fifty years ago as an ornamental because of its large, white, fragrant flowers. A yellow-flowered kind was also introduced. Both plants soon escaped from cultivation and now may be found growing naturalized at lower elevations on almost all the Islands in damp localities. The white- as well as the larger yellow-flowered gingerlily may be seen growing along the roadside between Hilo and Kilauea in great numbers.

The gingerlilies belong to the same family *Zingiberaceae* as the *awapuhi* (p. 111). Unlike the latter, however, they are tall, have only one kind of upright stem which is reminiscent of that of the banana (p. 105), and bear larger flowers of different structure. Although producing flowers in abundance, they rarely mature seed. They spread from place to place chiefly by means of their creeping and branching rootstocks.

Flowers of both kinds of gingerlilies are gathered and strung into fragrant garlands, or *lei*. These are usually offered for sale to travelers the moment they disembark on these shores by Hawaiian women dressed in flowing *holoku* (Fig. 28).

HAWAIIAN ORCHIDS

The *Orchidaceae* or Orchid Family is represented in these islands by only three native members, none of which grow elsewhere. All may be found within the boundaries of Hawaii National Park on the Islands of Maui and Hawaii, but they are so rare and so inconspicuous that few visitors will ever see them.

The orchid still known botanically by the old name of *Habenaria holochila* Hilleb.,* is exceptionally rare. It has been found on the Islands of Kauai, Molokai and Maui only. In the fog-swept

* The correct names of this plant and of certain others mentioned in the Guide are purposely omitted so as to avoid publishing new technical plant names amid strictly non-technical discussions. The proper vehicle for such changes in nomenclature is the writer's FLORA HAWAIIENSIS or NEW ILLUSTRATED FLORA OF THE HAWAIIAN ISLANDS.

Koolau Gap of Haleakala Crater, a spot where some of the most interesting plants survive, a few specimens have been seen growing in deep moss. This plant has a single erect stem one to two feet high, bearing toward the top more than a dozen small, yellowish flowers.

The other orchid, going by the cumbersome name of *Vrydagzyna sandwicensis* Lindl., is found in very dark, wet woods on all the larger islands. It has oblong, pointed leaves, and fleshy stems that creep along the ground and branch before rising to a height of four to ten inches. It therefore might be easily mistaken for a *Commelina* or day-flower, a plant which is incorrectly called *hono-hono* grass in the Hawaiian Islands. This orchid grows in some of the deep earthquake crevices in the vicinity of Kilauea-Iki and elsewhere.

The Hawaiian liparis or twayblade, *Liparis hawaiiensis* Mann, is probably the least rare of the three Hawaiian orchids and therefore here illustrated (Plate 29). Its native name is *awapuhiakana-loa*. It may be found on the flanks of Haleakala and in the vicinity of Kilauea growing in open woods, either on the ground or on moss-covered trunks of trees. The plant has a short stem, surrounded by several protective scales, that is surmounted by two pale leaves, each about three inches long. When these have manufactured a certain quantity of food, a flower stalk develops to a height of almost ten inches, bearing small, yellowish flowers. Upon their pollination by some insect, these develop into capsular fruits. At the same time food and water are stored in the basal part of the stem to such an extent that it swells enormously. When the seeds have been disseminated by the opening of the capsular fruits and the leaves have died, nothing living remains of the plant excepting the swollen stem with its attached roots. After being dormant for a certain length of time, the old stem sends forth a new one from near its base. This finally develops into a complete plant that will bear the coming season's flowers. Now if the tree trunk or ground should dry during periods of drought, the young liparis can continue growth by drawing upon the water and food stored in the old stem that gave rise to it. Though the liparis grows under the same conditions as the astelia (p. 100), it evades the danger of dying from lack of water in an entirely different way.

The Orchid Family has some of the smallest seeds known. They are as light as dust and, like the spores of ferns, can be



PLATE 29.—Hawaiian Liparis or Twayblade. (Original).

blown to great distances by even gentle currents of air. In the orchids so far studied by botanists, the seeds can develop into mature plants only if a fungus, called a mycorrhiza, can infect them and grow within their tissues. In this respect, the plants resemble the sexual stage of *psilotum* and of *lycopodium* previously described. In spite of this difficulty of developing to maturity, it is a mystery why only three kinds of orchids are native to the Hawaiian Islands when these plants are so numerous in other warm and tropical countries, and their seeds are so easily transported by the wind over extensive bodies of water.

CASUARINA, BEEFWOOD OR FALSE IRONWOOD

Several kinds of beefwood or false ironwood trees will probably attract the attention of the visitor on his way to Hawaii National Park. All belong to the group of plants called *Casuarina*, comprising the *Casuarinaceae* or *Casuarina* Family. The entire family, consisting of about thirty kinds of plants, is peculiar to Australia and to some of the Pacific Islands. None are native to the Hawaiian Islands, but four or five have been introduced.

From a distance the beefwood trees (Plate 30) appear like tall pines bearing long, drooping needles and small cones. Upon closer inspection, however, one will see that these plants have little in common with pines. The structures that seem to be needles or true leaves are actually long, green, jointed branches that wave pendent in the breeze. At each joint or node are five to fifteen minute teeth, the number varying according to the particular kind of *Casuarina*. The teeth are actually the degenerate leaves that one would expect branches, no matter how specialized, to bear. These teeth are homologous to the needles of the pine, not analogous to them.

Some of the slender, green branches end in catkins. These consist of several whorls of minute leaves bearing pale staminate, or "male," flowers that are greatly reduced in size and structure. The pistillate, or "female," flowers, on the other hand, are borne clustered on shorter branches. The female flowers are also greatly simplified, each consisting of a single pistil with its scarlet end receptive to pollen. After the pollen has reached the pistil and the ovules within begin to develop into seed, the entire catkin increases in size to become a cone-shaped structure, at first green, but finally brown. This later sheds the ripe seed. It is not like the cone of the pine tree because that tree never forms pistils.



PLATE 30.—*Casuarina* or False Ironwood. (Original).

The wood of the beefwood or false ironwood, likewise, is different from that of the pine. It is dark red in color as the name beefwood implies, while that of pine is light yellow; it is extremely hard as its other name indicates, while pine is soft. Study of the two woods under the microscope will show still greater differences, that of the beefwood being more like oak wood than pine.

Obviously the common beefwood, like the cactus, is highly specialized for existence in very dry regions. Its leaves have degenerated to such an extent that they are almost non-functional, the green stems functioning in their stead. By dispensing with leaves the plant has enormously reduced the surface that it would otherwise expose to the drying rays of the sun. And to conserve the moisture that would normally escape from the inner tissues of the plant, the microscopic air-pores or stomata necessary for respiration have sunk into sheltered grooves in the slender green stems. Thus the beefwood can flourish in regions of little rainfall where most plants with normal leaves would perish from drought.

The beefwoods have been introduced into the Hawaiian Islands for their ornamental and especially their economic value. They grow rapidly on the hot, coastal dunes and act as valuable sandbinders and windbreaks where few other trees will live. They also grow in the drier uplands, thus being of value in reforesting regions from which the more interesting native trees have been exterminated. Some beautiful groves may be seen in Makawao, Maui, the town through which most travelers passed on their way to Haleakala Crater before the road to the Rest House had been constructed.

PEPEROMIA OR ALAALAWAINUI

Only two groups of plants in the Hawaiian Islands belong to the *Piperaceae* or Pepper Family. The one is *Piper*, to which group the true black pepper of commerce belongs; the other is *Peperomia*.

Piper is represented locally by *Piper methysticum* Forst., the *awa* of the natives. This was undoubtedly introduced by the Hawaiians in prehistoric times and grown in the woods under conditions of semi-cultivation. It is a strong narcotic herb becoming as much as nine feet high. It was formerly much used by all classes of Hawaiians as a valuable medicine, and by the chiefs in large quantities as a pernicious drug. It does not grow in the Park, but is found in considerable abundance on the Island of Hawaii in the District of Puna and along the government road



PLATE 31.—*Peperomia* or *Alaalawainui*. (Original).
Fruit enlarged.

leading from the city of Hilo to Kilauea. A closely related plant, which has been mistaken for the true betel pepper, also grows in the Islands. This, however, was introduced by the Orientals during the latter half of the nineteenth century.

The group known as *Peperomia*, or in Hawaiian as *alaala-wainui*, is represented in the Islands by well over a hundred kinds. These are fleshy herbs varying from a height of a few inches to an extreme of three or four feet. They are typically found on the ground, though a few kinds, exemplified by *Peperomia reflexa* (L.f.) Dietr., figured on Plate 31, are partial to growing on rocks and trunks of trees.

Most peperomia, as their succulent character attests, are provided with water-storage tissues. This enables the plants to thrive during dry seasons when other plants would die. A surplus supply of water is simply retained in certain cells for possible future use during periods of drought. Another interesting feature in many of these plants is their leaf arrangement. As in the figured specimen which may be observed in the Kipuka Puau, near Kilauea, leaves appear to be borne in whorls of four each. This is not strictly true. Only two leaves are actually borne together at a single joint, or node. Alternate internodes, however, are so reduced in length that the two adjoining nodes are always approximated, their two separate pairs of leaves therefore simulating a single whorl of four leaves. In flower structure, these plants are greatly degenerate. The flowers, borne on an erect stalk, are minute. Each consists of a single pistil and two stamens sunk in a depression of the stalk and protected by an axillating scale, or bract. As the pistil matures into a minute, seed-like fruit, it partly extrudes from the depression in which it has developed. The fruit, being sticky, is then readily scattered by birds or other animals that happen to come in contact with it.

The peperomia were not of much value to the Hawaiians. They were occasionally used in medicine and in the manufacture of a gray dye for staining *kapa* (p. 132).

BREADFRUIT OR ULU

The breadfruit (Plate 32) is known as *ulu* by the Hawaiians. Technically it is *Artocarpus communis* Forst. It belongs to the *Moraceae* or Mulberry Family to which the common fig and the banyan, or rubber tree, also belong. It can be seen by the visitor on his way to both sections of the Park, or even within the

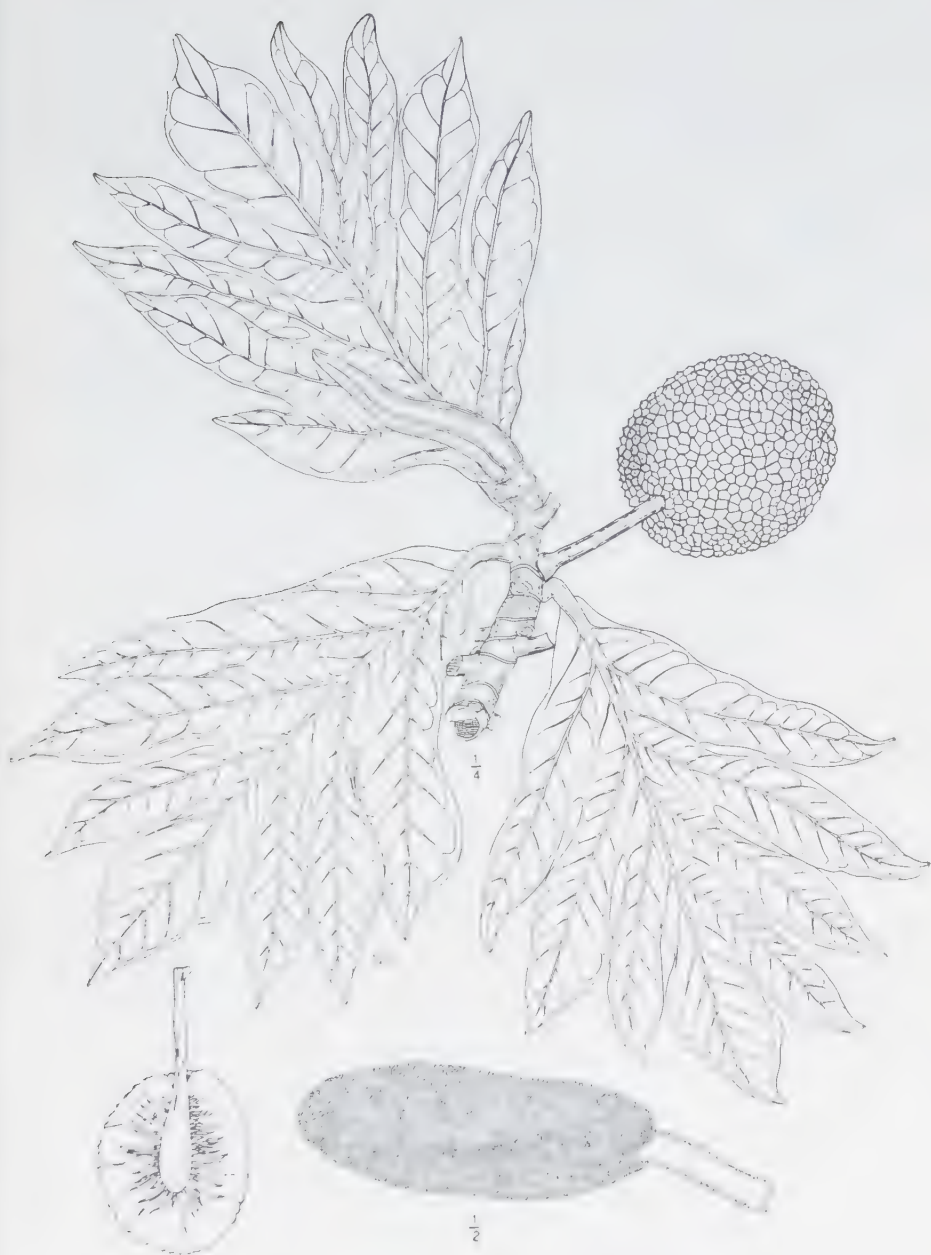


PLATE 11 = Breadfruit or Ulu. (Original).

End of branch with collective fruit; longitudinal section of collective fruit; staminate flower cluster.

Kilauea Section if he has the opportunity to tramp over the stretches of land near the coast.

The breadfruit is not strictly a native plant, but was undoubtedly brought here in very early times by the progenitors of the Hawaiian race. The reasons for considering the plant foreign to this flora are its inability to produce seed and to disseminate itself, its occurrence near native dwellings or where these have stood, and the traditionary account of its introduction. It is said to have been brought from the Island of Upolu in the Samoan group around the twelfth century by the chief Kahai and first planted at Kualoa, Island of Oahu.

The breadfruit is a tall tree of striking appearance. Like its relatives, the fig and the banyan, it exudes abundant milky juice when cut. It has large, lobed leaves and foliar stipules, or structures which protect the leaf when it is yet young. The same individual has two kinds of flower clusters. The staminate, or "male," are long club-shaped structures consisting of thousands of minute pollen-bearing flowers. The pistillate, or "female," clusters are almost spherical and consist of thousands of pistillate flowers. After pollination has taken place, each one develops into a fruit. As these increase in size, they press against each other with such force that they almost lose their individuality. They are no longer round and separate, but angular and united. Consequently the entire breadfruit, sometimes a foot across, is not a single fruit but a collective fruit. This is similar to the condition found in the pineapple (p. 87) and the *noni* (p. 284).

The trunk of the breadfruit or of the coconut was fashioned into the *pahu* (p. 75), a large drum. To make this, a section of the trunk at least one foot in diameter and about two feet long was laboriously chipped out part way from each end. In this manner a cross section of the log was left as a diaphragm one-third of the distance from the base. The lower chamber was often carved, while the upper had a head made usually of the scaleless skin of the shark. This was fastened to the sides of the cylinder by means of cord frequently made of the fibers found in the husk of the coconut. The tone of the *pahu* was produced with the palm of the hand; never with a stick. It was the beating of these drums that emphasized the rhythm of most *hula* dances (p. 53).

Surf boards, *papa hee nalu*, were often made of the wood of the breadfruit because of its lightness. These boards varied from



FIGURE 29.—Hawaiian youth riding on *papa hee nalu*, or surf board. (Original).

three feet in length and six to eight inches in breadth, to fourteen feet in length and about two feet in breadth. Some were flat though most of them were slightly convex on both sides.

On days when the waves were exceptionally high, both men and women advanced toward the surf, lying prone upon their boards, propelling themselves forward with quick breast strokes. In this position, the feet were used as a rudder. If the right foot was allowed to drag in the water, the board quickly turned to the right; if the left foot, then the board responded and turned in that direction. On meeting the waves as they roll toward shore, the surf-rider glides over those that are smooth, and plunges under or through those that are high or breaking.

After propelling themselves far beyond the line of breakers, these stalwart men and women faced shoreward and remained in that position, bobbing up and down in the choppy sea until a very high swell approached. Then they placed themselves before it, either lying or standing upright on their boards, and gave two or three propelling strokes with their outspread hands. As the great wave dashed onward and broke into a huge comber, the surf-riders (Fig. 29) balanced themselves on the boards, which were inclined at an angle just before the crest of the wave. In this manner they dashed toward shore at a tremendous speed, often exceeding forty miles per hour. Now and then a swimmer was dislodged from his board, as it raced ahead of the breakers, and sank in the foam to be mercilessly twisted in the whirling water. But the other riders dashed gracefully toward shore until the wave became so reduced in size and force that the board slackened its speed and finally stopped.

Today surf-riding is still a favorite sport practiced at Waikiki Beach, Honolulu, where the breakers begin to form far from shore because of the expanse of shallow water. Here the visitor may participate in this thrilling Hawaiian pastime under expert native instructors.

The surf boards were usually stained black and preserved with utmost care. After using, they were dried thoroughly in the sun, rubbed with coconut oil, often wrapped in *kapa* (p. 132), and suspended in some part of the house. This oiling prevented the boards from becoming water-logged with frequent use.

From the bark of the breadfruit the Hawaiians at times made an inferior grade of *kapa*. They even used the male flower cluster, the *poule*, mixing it with the fiber of the *wauke* (*Brousson-*

etia papyrifera (L.) Vent., to form a rare kind of *malo*, or loin cloth. This custom probably arose from the belief in the Doctrine of Signatures, a superstition held by most races and but recently abandoned by the Caucasian.

The stipules of the breadfruit were used as a fine abrasive. For example, the skilled Hawaiian woodworker first seasoned his wood by cutting it into blocks of suitable size and burying these in the mud of his taro (p. 81) patch. Here they soon darkened and acquired the appearance of having seasoned for many years. He next fashioned these blocks into domestic articles, such as calabashes, by means of stone implements. Fine coral or lava was then employed as an abrasive to remove the rough surfaces. This was followed by treatments with soft, brittle lava, next with pumice, or possibly charcoal, with bamboo leaves, and finally with dried breadfruit stipules.

As an article of food, the breadfruit was not of much importance in Hawaii. The fruit was baked in an *imu* and then eaten or, after baking, preferably peeled of its outer skin and deprived of its central, woody core. It was then pounded into a food similar to *poi* (p. 82). Where taro (p. 79) was not available, breadfruit was used in making a coconut pudding, called *paipai*, similar to *kulolo* (p. 77). To fatten their domestic pigs, introduced centuries before the coming of Captain Cook, the Hawaiians gave them breadfruit, and taro and sweet potato peelings. Strange as it may seem, the Hawaiians never preserved the breadfruit in pits dug in the earth as did the Samoans, although in this state such provender would remain edible for many months.

To make their precious war cloaks (Fig. 14), *kahili* (p. 206), helmets (p. 52), and certain idols (p. 52), the Hawaiians caught various forest birds, especially the *mamo* (p. 288), *oo*, *iʻiwi* and *apapane* for their plumage. The *mamo*, now extinct, was black in color but possessed a small tuft of yellow feathers under each wing, not two feathers under each wing as so many relate. The *oo* is likewise black and yellow, while the *iʻiwi* and the *apapane* are black and red. The royal birdcatchers caught these birds by smearing the sticky juice, termed *kia* or *kepau*, of the breadfruit, endemic lobelia (p. 288), or of the fruit of plants belonging to the groups called *Rockia* and *Calpidia* on long, baited poles, *laukia*, or on posts, *poukia*. These they scattered thickly about the haunts of the birds, which, alighting upon them, thus became caught by their feet. The hunters were instructed by Kanehameha to liberate

these birds after plucking their choice feathers so that a new supply might grow. After washing their feet of the adhering sticky mass of birdlime with *kukui* nut oil (p. 193) or with sugar cane juice they were freed, having suffered no serious injury.

MAMAKE

The *mamake* of the Hawaiians, of which several kinds are known, belongs to the group *Pipturus*. All are members of the *Urticaceae* or Nettle Family. They were the most abundant fiber plants of the ancient Hawaiians, being found throughout the Islands in open woods, especially below 4,000 feet elevation, in many perplexing varieties and forms. Very many of these plants may be seen along the road that leads from Hilo to Kilauea, growing with the *icie* (p. 49), chiefly in the burned-over forest south-east of the village of Olaa. Within the boundary of the National Park a different kind (Plate 33) may be found. This can best be studied near the Thurston Lava Tube.

The *mamake* is a shrub or rarely a small tree with somewhat hairy stems. The leaves are ovate in shape, light green on the upper side, but underneath sometimes almost white with very fine, short hair. They possess three main veins which are often bright red in color. The flowers, of which there are two kinds, are borne in very inconspicuous clusters because the plant need not attract insect visitors to effect cross-pollination. Some individuals have only staminate, or "male," flowers and some have only the pistillate, or "female." Still others have both kinds of flowers on the same plant. The staminate flowers bear stamens which elastically hurl their dry, powdery pollen into the air. Borne by the wind, some of this may fall upon the pistillate flowers and fertilize the ovules contained within them. Only then will seeds be formed which will mature in the drying pistils. The groups of short, united flower stalks of the pistillate cluster, in the meantime, also develop. Each becomes a waxy-white, fleshy structure about half an inch in diameter, harboring the dried, seed-like pistils in open depressions. These strange fruits built up of many flower stalks, though insipid to our taste, are palatable to birds, which eat them as well as the indigestible, seed-containing pistils. The seeds thus pass through the body of the bird unharmed and may finally become planted in new localities. These fruits were occasionally eaten by the Hawaiians as a laxative and given to children as a remedy for thrush, or *ca* (p. 20).



PLATE 33.—Mamake. (Original)

The *mamake* is the favorite host of a green caterpillar which finally pupates and emerges as the beautiful, reddish-brown Kamehameha butterfly, known scientifically as *Vanessa Tameamea* Esch. This insect and a small metallic green kind are the only butterflies native to the Hawaiian Islands. The closest relative of the Kamehameha butterfly, strangely enough, seems to be *V. callirhoe* Fabr., native to Madeira.

The plant that furnished the best quality of bark cloth for the Hawaiians was not the *mamake* but the *wauke* or paper mulberry, *Broussonetia papyrifera* (L.) Vent. This plant, whose native home is not definitely known, was carried to Hawaii and throughout the Pacific by the Polynesians in their migrations. In these islands it was carefully cultivated for the making of *kapa* until two or three generations ago when the customs of the white man more generally displaced those of the Hawaiian. Even today, *wauke* plants may be found persisting in an occasional valley as, for example, near Kamalo on Molokai. The *mamake*, however, was the most abundant fiber plant and produced the second best type of *kapa*. Its fiber was of somewhat coarser quality. As the making of bark cloth from the *wauke* and the *mamake* was an important occupation of the Hawaiians up to a few generations ago, it is not amiss to describe it in some detail. Because no very good contemporary account of the local manufacture has come down to us, we can do no better than follow W. T. Brigham in *Ka Hana Kapa*, one of his many excellent monographs on Hawaiian customs. He quotes from Sir Joseph Banks' Journal concerning the manufacture of cloth in Tahiti from *wauke* bark, a method essentially the same as that practiced with *wauke* and *mamake* in Hawaii.

Sir Joseph, who accompanied Captain Cook, the explorer, in his first voyage of discovery in 1768, states that the *wauke* is cultivated with much care and that young plants of one or two years' growth only are used. These are thin, straight and tall and bear no branches because as often as the lower buds show a tendency to grow, they are removed with their axillating leaves. He then describes the method of manufacturing the bark into cloth as follows:

"The thin bark they make thus; when the trees have grown a sufficient size they are drawn up, and the roots and tops cut off and stripped of their leaves; the best of the [*wauke*] are in this state about three or four feet long and as thick as a man's finger.

The bark of these rods is then slit up longitudinally, and in this manner drawn off the stick; when all are stripped, the bark is carried to some brook or running water, into which it is laid to soak with stones upon it, and in this situation it remains some days. When sufficiently soaked the women servants go down to the river, and stripping themselves, sit down in the water and scrape the pieces of bark, holding them against a flat smooth board, with the shell called by the English shell merchants Tiger's tongue (*Tellina gargadia*), dipping it continually in the water until all the outer green bark is rubbed and washed away, and nothing remains but the very fine fibres of the inner bark. This work is generally finished in the afternoon: in the evening the pieces are spread out upon plantain leaves, and in doing this I suppose there is some difficulty, as the mistress of the family generally presides over the operation. All that I could observe was that they laid them in two or three layers, and seemed very careful to make them everywhere of equal thickness, so that if any part of a piece of bark had been scraped too thin, another thin piece was laid over it, in order to render it of the same thickness as the rest. When laid out in this manner, a piece of cloth is eleven or twelve yards long, and not more than a foot broad, for as the longitudinal fibres are all laid lengthwise, they do not expect it to stretch in that direction, though they well know how considerably it will in the other.

"In this state they suffer it to remain till morning, by which time a large proportion of the water with which it was thoroughly soaked has drained off or evaporated, and the fibres begin to adhere together, so that the whole may be lifted from the ground without dropping in pieces. It is then taken away by the women servants, who beat it in the following manner: they lay it upon a long piece of wood [in the Hawaiian Islands termed *kua kuku*, Fig. 30], one side of which is very even and flat, this side being put under the cloth: as many women then as they can muster, or as can work at the board together begin to beat it. Each is furnished with a baton [in the Hawaiian Islands termed *ie kuku*, Fig. 31, in center] made of hard wood . . . it is about a foot long and square with a handle*; on each of the four faces of the square are many small furrows, whose width differs on each face, and which cover the whole face. They begin with the coarsest side,

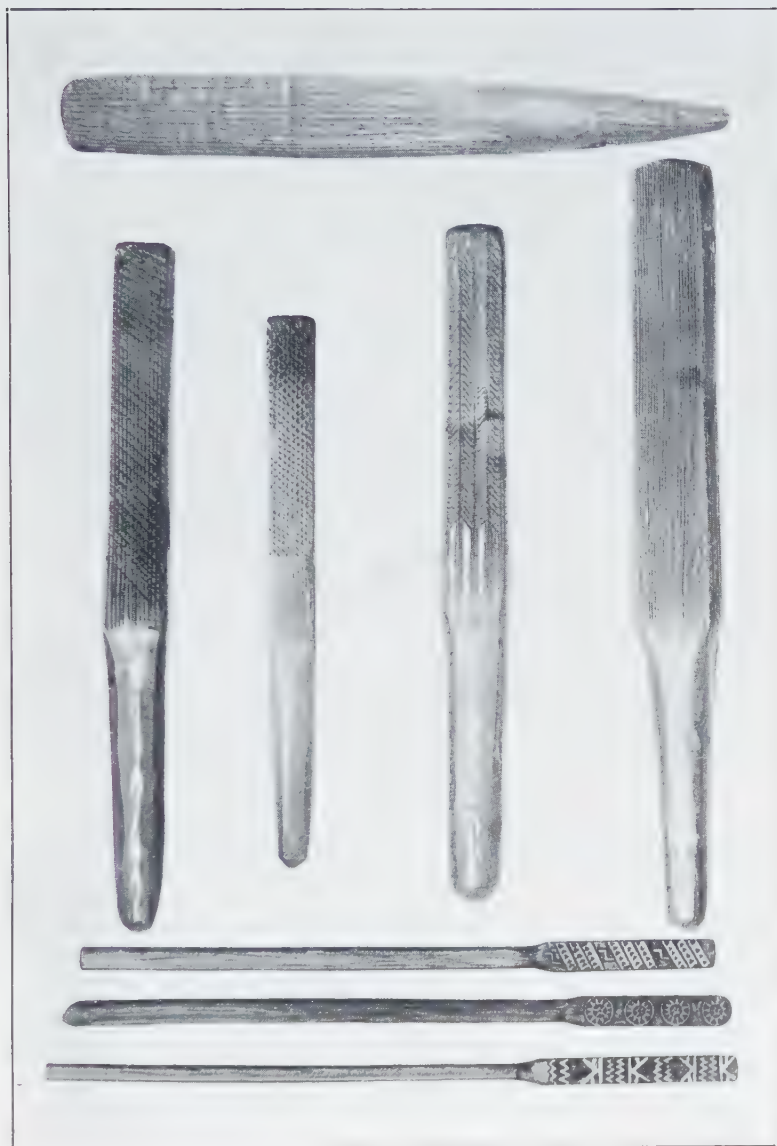
* Before flat-sided beaters were used, a round one, termed *hohoa* (Fig. 31, at top), was employed.

keeping time with their strokes in the same manner as smiths, and continue until the cloth, which extends rapidly under these strokes, shows by the too great thinness of the grooves which are made in it that a finer side of the beater is requisite. In this manner they proceed to the finest side, with which they finish; unless the cloth is to be of that very sort which is almost as thin as muslin. In making this last they double the piece several times, and beat it out again and afterwards bleach it in the sun and air, which in these climates produces whiteness in a very short time.



FIGURE 30.—Hawaiian woman, holding *ic kuku*, beating bark into *kapa* cloth on *kua kuku*.

"Of this thin cloth they have almost as many different sorts as we have of linen, distinguishing it according to its fineness and the material of which it is made. Each piece is from nine to fifteen yards in length, and about two and a half broad. It serves them for clothes in the day and bedding at night. When, by use, it is sufficiently worn and becomes dirty, it is carried to the river



(Beaters from collection of Degener; sticks adapted from W. T. Brigham.)

FIGURE 31.—One round *kapa* beater, or *hohoa*; four four-sided *kapa* beaters, or *ie kuku*; three *kapa* printing sticks, or *ohēhapalapala*.

and washed, chiefly by letting it soak in a gentle stream, fastened to the bottom by a stone, or, if it is very dirty, by wringing it and squeezing it gently. Several of the pieces of cloth so washed are then laid on each other, and being beaten with the coarsest side of the beater, adhere together, and become a cloth as thick as coarse broad-cloth, than which nothing can be more soft or delicious to the touch. This softness, however, is not produced immediately after the beating; it is at first stiff as if newly starched, and some parts not adhering together as well as others it looks ragged, and also varies in thickness according to any faults in the cloth from which it was made.

"To remedy this is the business of the mistress and the principal women of the family, who seem to amuse themselves with this, and with dyeing it, as our English women do with making caps, ruffles, etc. In this way they spend the greater part of their time. Each woman is furnished with a knife made of a piece of bamboo cane, to which they give an edge by splitting it diagonally with their nails. This is sufficient to cut any sort of cloth or soft substance with great ease. A certain quantity of a paste made of the root of a plant which serves them also for food, and is called by them Pea . . . [*Tacca* sp.], is also required. With the knife they cut off any ragged edges or ends which may not have been sufficiently fixed down by the beating, and with the paste they fasten down others which are less ragged, and also put patches on any part which may be thinner than the rest, generally finishing their work, if intended to be of the best kind, by pasting a complete covering of the finest thin cloth . . . over the whole. They sometimes make a thick cloth also of only half-worn cloth, which having been worn by cleanly people is not soiled enough to require washing.

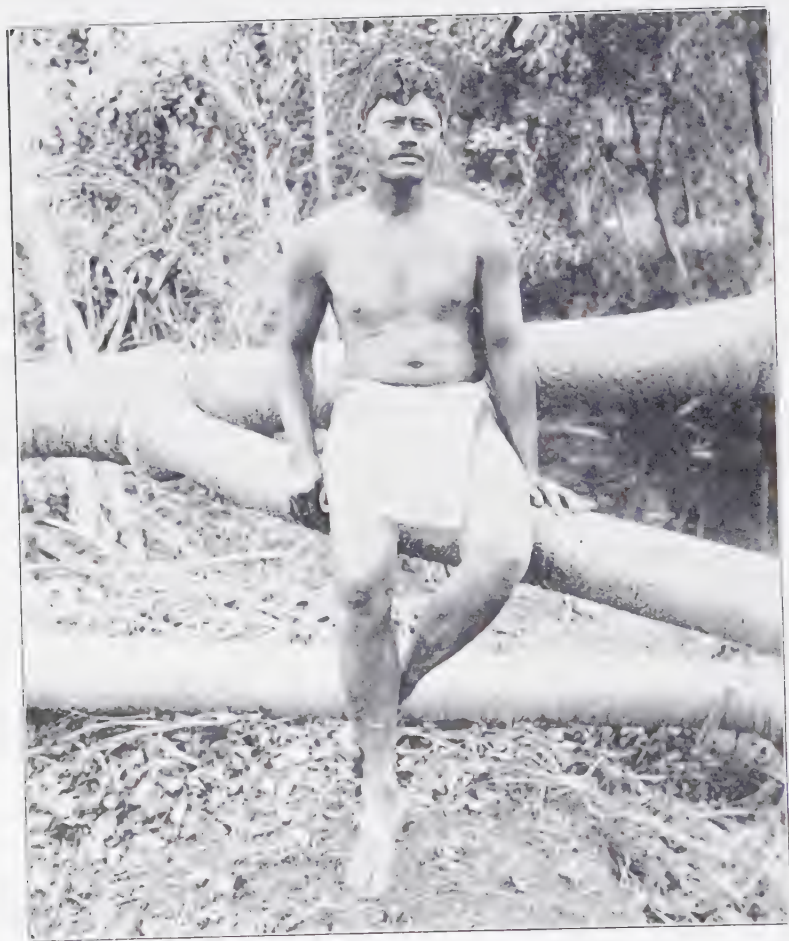
"The cloth itself, both thick and thin, resembles the finest cottons, in softness especially, in which property it even exceeds them; its delicacy (for it tears by the smallest accident) makes it impossible that it can ever be used in Europe, indeed it is properly adapted to a hot climate. I used it to sleep in very often in the islands, and always found it far cooler than any English cloth."

Cloth of this type made by the Hawaiians is called *kapa*, commonly but less correctly written *tapa* by those who are not of native ancestry. The origin of the word indicates the essential procedure necessary for making the stuff, being derived probably from the Hawaiian *ka*, meaning "the," and *pa*, meaning "beaten."

Kapa was frequently stained or figured with various designs in black, brown, purple, red, yellow, and very rarely blue or green. This was accomplished in three different ways. Apparently the simplest method was that of dipping the *kapa* in a dye. The result may then have been considered sufficiently ornamental and no further coloring attempted. Or the dipped *kapa* may have had lines or other designs in different colors painted upon it. The lines were made by drawing across the cloth with the end of a bamboo stick, called *lapa*, steeped in dye, that had been cut into prongs like those of a fork. The other figures were often painted with a brush made from a segment of the *hala* fruiting head (p. 47). The highest type of ornamentation, however, was accomplished by printing. Quoting William Ellis, an eyewitness of this method in Hawaii, we read: "Their manner of printing is ingenious. They cut the pattern they intend to stamp on their cloth, on the inner side of a narrow piece of bamboo [called *ohchapala*, or better *ohchapalapala*, Fig 30, at bottom], spread their cloth before them on a board, and having their colors properly mixed, in a calabash by their side, dip the point of the bamboo, which they hold in their right hand, into the paint, strike it against the edge of the calabash, place it on the right or left side of the cloth, and press it down with the fingers of the left hand. The pattern is dipped in the paint after every impression, which is repeated till the cloth . . . is finished."

Some of the dyes used in coloring *kapa* and some of the perfumes employed in rendering it fragrant are mentioned in the discussion of the plants from which they were derived (see pages 40, 93, 102, 124, 145, 173, 178, 197, 200, 249, 251, 286, 304). Some of the dyes for the *kapa* were permanent or fast without any special treatment of the cloth, while in other cases it was necessary to use various mordants to fix the dye, as seawater, mud, urine or burnt coral sand. The complicated method of making many of these dyes has already become a lost art. The procedure for making most of the others will be lost to posterity within a generation unless the few remaining people that possess this interesting knowledge put it into writing without delay. The good and bad customs, the history and the myths of both the White Race and of the Oriental Race may be found filling hundreds and even thousands of volumes where they can be studied by anyone until the end of time. But the knowledge of most of the customs, history, myths and beautiful *mele* of a great Pacific Race, the Polynesian, is gradually passing into oblivion because

so many of the older people belonging to that race neglect to record, in some language, their priceless information and the interesting sayings that they remember their parents or grandparents to have used. It is safe to say that practically every man and woman of Hawaiian ancestry, born before 1880, possesses knowledge or impressions well worthy of record in a book on Hawaiian civilization.*



(Courtesy R. J. Baker.)

FIGURE 32.—Hawaiian, leaning against *hala* trunk, wearing *malo* or loin cloth.

* Regard for the ancient customs of the Hawaiians appears to be on the wane. So little interest seems manifest in local ethnology that some of the very few men in the Islands trained in this science are obliged to enter other fields for a livelihood. Such men should be enabled to gather the wealth of information still locked in the memories of the older Hawaiians.

The *kapa* was always made by women, the chiefesses vying with one another in designing intricate and beautiful patterns. Its main purpose was that of furnishing a suitable material for clothing, although it was used also for bed coverings, wicks, sandals and for religious purposes.

In a semi-tropical country where the greater part of the inhabitants live within a few hundred yards of the ocean and gain their chief livelihood from it, the problem of clothing is relatively unimportant. For that reason, the dress of the early Hawaiians was scant. It was a little more abbreviated than the costumes



(Courtesy R. L. Baker.)

FIGURE 33.—Hawaiian warrior, with spear or *pololo*, wearing *malo*, or loincloth.

worn today by men and women for swimming and relaxation on the beaches of Hawaii and throughout the civilized world. That of the Hawaiian man was the *malo* (Fig. 32). This consisted of a strip of cloth nine to twelve inches wide and as many feet long. It was usually adjusted by holding one end under the chin and passing the rest of the cloth backward between the legs. It was then drawn up to and around the waist over the vertical end of the strip still held by the chin. The free end was then twisted around the part encircling the waist in the back (Fig. 33), while the other end was allowed to fall gracefully down below the navel. *Malo* of several qualities and of various designs were made. These frequently indicated the social status of the wearer. For a commoner to wear the *malo* of a chief was a serious offence, punishable with death. In 1818 the last human sacrifice was made at the City of Refuge, or *puuhonua*, at Honaunau, Island of Hawaii, because of the breaking of this *kapu*. During battle, it is said, the common soldier and frequently even the chief laid the *malo* aside because of the ready hold it would otherwise give of his person to an enemy during hand to hand encounters.

The costume of the Hawaiian woman corresponding to the *malo* was the *pau*. This was commonly twenty-five to thirty-five inches wide and nine to fifteen feet long. It thus reached from the waist half way down to the knees. It usually consisted of five sheets of cloth of which the four inner were commonly white or yellow, while the outer one was usually beautifully printed with red, yellow and black and then, according to some authorities, covered with a varnish (p. 198) to protect the colors, and to make the cloth more durable and somewhat waterproof. The *pau* worn by the queens at special occasions were so incredibly long that the wearer was at times surrounded by seventy thicknesses of cloth.

A third article of clothing that might better be considered a cape or wrap for wear during cold weather, was the *kihei*. It was worn by both men and women, especially the aged, by passing it under one arm and tying it over the shoulder opposite. Children up to nine or ten years of age went entirely naked.

The Hawaiians used no footwear except when traversing some of the flows of extremely jagged and sharp lava on the Island of Hawaii. Then temporary sandals or bandages, called *kamaa*, were made of braided *kapa*, of the bark of the *hau* (p. 213), of the leaves of the *la-i* (p. 95), of the leaves of the *hala* (p. 43), or of any other suitable material available.

Bed coverings, termed *kapa moe* or *kuinakapa*, were used for warmth at night by the higher classes at least. These consisted of five separate sheets of thick *kapa*, each three to four yards square, sewed together only at one end usually by means of a *kapa* tape. The *kilohana*, or upper sheet of this set, was often elaborately decorated.

Fragments of old *kapa* were used as wicks in the stone *kukui* lamps figured elsewhere (p. 196), while the old *kapa moe* were stripped into string-like lengths. One of these was then loosely coiled and lit from the fire that had been ignited laboriously by friction (p. 215) before that was extinguished. Such strings slowly smoldered on like a fuse and thus offered a convenient way of relighting the ovens or lamps when necessary.

Kapa was used in the usual marriage ceremony, the bridegroom casting a piece over the bride in the presence of her parents and relatives. Or a chief or friends threw the *kapa* over both the youth and the maiden. If the lovers were of high rank, however, they came in state with their attendants and joined noses, *honi*, the Polynesian sign of affection, before the assembled multitude amid shouts that the chiefs are married. A *luau*, or feast, invariably followed these ceremonies. It is unlikely that a husband divorced his wife with as much ease as is commonly stated. If divorce was not mutually agreeable and the wife had done no wrong, the husband would doubtless hesitate before incurring the enmity of his wife's relatives.

White or red *kapa* was used in the *hciau*, or temples, to clothe the idols, and white *kapa* was used for the flat sides of tall, obelisk-like structures, called *anuu*, built usually of bamboo, down which the voice of the god should pass from heaven to the oracle standing within. These *anuu* were sometimes fifty feet high and usually four to five feet square. A small white *kapa*, called *oloa*, was placed over the idols while an incantation was being chanted. White *kapa* on a stick, placed in a path or bound around the trunk of a tree, indicated that trespassing was forbidden or that the fruit of the tree was *kapu* (p. 109).

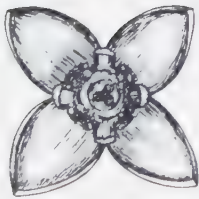
The making of *kapa*, according to the old Hawaiians, was responsible for the naming of the Crater of Haleakala. Maui, so the myth relates, lived with his mother, Hina, on the western part of the Island of Maui. His mother, who was wont to make *kapa*, found difficulty in drying her product because the days were so short. Almost as soon as she spread her *kapa* out to dry, the sun

set and she was obliged to take it into the house again to protect it from the dew and rain. Maui resolved to help her. After a little reconnoitering he discovered that the sun passed directly over the enormous crater forming the central part of eastern Maui. He returned home and then journeyed to Waihee where he cut down all the coconut trees to manufacture a strong rope from the husks of the nuts. Armed with his rope he ascended the mountain again, made a noose, and with it caught one of the sun's larger rays with which she was walking across the earth. This he broke off. He continued catching and breaking the larger rays until only the shorter and weaker ones remained. Now having the sun in his power he threatened to kill her for having traveled so fast. Upon begging for her life and promising to go more slowly hereafter, Maui liberated her. From that time on the days were longer, Hina could more easily dry her *kapa*, and the crater was called "sun snarer." This name should be properly spelled *Alchekala* in Hawaiian and not *Halcahala* which means "house of the sun." The largest of the cinder cones within the crater is still named after Maui as that is where his exploit is supposed to have taken place.

Today *kapa* is no longer made in the Hawaiian Islands because all the men and many of the women of native ancestry wear the usual costume of the European. Most of the older women fortunately still adhere to the custom of wearing the stately *holoku* (Fig. 28) of the "Mother Hubbard" type, introduced by the American missionaries in the early days. This dress, however, is not made of native cloth. The only material for sale in the Islands that resembles Hawaiian *kapa* closely is *siapo*, the *kapa* of the Samoans. This may be purchased for a reasonable sum. The buyer should insure the continued making of true native Samoan *kapa* by refusing to accept pieces that appear to have been colored by other than the native dyes. For want of Hawaiian *kapa*, a Samoan sample is here inserted as a bookmark.

SANDALWOOD OR ILIAHI

More than fifteen kinds of true sandalwood exist. All belong to the group known as *Santalum* which, with about twenty-five other related groups of plants, comprises the *Santalaccae* or Sandalwood Family. Though of this family the members found in the Hawaiian Islands have been twice monographed, much work



4

PLATE 34.—Sandalwood or Iiiahi. (Original).

must yet be done before we can be certain whether eight or more kinds are peculiar to these islands.

Sandalwoods are shrubs or trees which, with very few exceptions, have a strange method of gaining food. This method is hidden from view until we carefully wash the soil away from one of the plants. Then we see that the roots of this plant, as in most kinds, have ramified in all directions in search of moisture and soil salts carried in solution. But unlike the roots of other plants, some grow toward those of certain neighboring shrubs and trees and actually send sucking organs, called haustoria, into them. By this means, the sandalwood is able to rob them of some of their food. The result of such partial parasitism over countless generations is that the plant has become degenerate. The leaves are no longer obliged to manufacture the entire supply of food necessary for the plant out of water, air and soil salts with the aid of sunlight which falls on the green chemical, chlorophyll, within them. Hence they have become comparatively small, thick and pale green.

The sandalwoods native to these islands are called *iliah*i by the Hawaiians. All have small four- or five-parted flowers that are either greenish-yellow or red. In the vicinity of Kilauea Crater, particularly along the Sandalwood Trail, the Kilauea sandalwood known as *Santalum paniculatum* Hook. & Arn., may be seen (Plate 34). This is a shrub or small tree, rarely exceeding fifteen feet in height, bearing greenish flowers. Though not particularly attractive, it is worth visiting because of the commercial and historical importance of plants like it. In Koolau Gap within Haleakala grows another kind, named after the crater where it grows, *Santalum halcakalae* Hilleb. This bears dense clusters of very beautiful, dark red flowers.

The heartwood of the sandalwood tree has always been highly prized because of its close grain and fragrance. It was particularly valued in the Orient where it was burned extensively for incense, used in ornamental carving and cabinetwork, and used as a repellent against insects. Before the discovery of the Hawaiian Islands by Captain Cook in 1778 and '79, almost all such wood was derived from the white sandalwood, *Santalum album* L., of the East Indies. But soon after the discovery, the presence of sandalwood growing here in great abundance in the drier regions became known to the world. The Hawaiians, of course, had long known the properties of this wood as their name *lauu aala*, meaning

"fragrant wood," indicates. They used the powdered heartwood as a perfume and frequently sprinkled it among their *kapa* (p. 132) to offset the objectionable odor that was particularly strong shortly after its manufacture.

In 1791 Captain John Kendrick, a New Englander then engaged in the fur trade between the northwest coast of America and China, left three of his sailors on Kauai to collect sandalwood and pearls for him until his return voyage from Boston. Thus began the sandalwood industry in the Islands, which grew to huge proportions, being at its height from 1810 to about 1820. Due to the cutting of all trees of marketable size and to lack of replanting, the industry ended before 1845. It is estimated that during this time the Hawaiian Islands were enriched from the sale of the wood for export to Canton by three or four millions of dollars in money and merchandise, mostly the latter. As the Chinese name of sandalwood is *tan hcong*, meaning "fragrant tree," these islands became known to them as *Tan Hcong Shan*, or the "Sandalwood Country." This was later shortened to *Tan Shan*.

The sale of sandalwood at \$125 and upward per ton was a ready means of obtaining money with which to buy necessities and some of the most extravagant luxuries. It was also acceptable for barter. For example, if a vessel was to be bought, the chief agreed to give an amount of sandalwood in exchange equal to its bulk. A pit was then dug with dimensions equal to the greatest length, depth and breadth of the hull of the vessel desired. This was then filled with sandalwood, which quantity amounted to the purchase price.

Because of their desire for wealth, the chiefs obliged their retainers to gather sandalwood in great quantities in addition to demanding the same commodity in payment of taxes. Their men were not only forced to search for the tree, but also to fell it, cut it into pieces eighteen inches in diameter and from six to eight feet long, and to carry it like so many pack horses to the royal storehouses. As the forests became more and more depleted of these valuable trees, the common people were forced to undergo greater hardships to satisfy their masters' wants. Little time for agriculture remained so that once actual famine threatened the Islands. What this industry meant to the common people is clear from a quotation from William Ellis who was staying in the District of Kohala, Island of Hawaii, around that time:

"Before daylight . . . we were roused by vast multitudes of

people passing through the district from Waimea with sandalwood. . . . There were between two and three thousand men, carrying each from one to six pieces of sandal wood, according to their size and weight. It was generally tied on their backs by bands made of ti leaves [*la-i*], passed over the shoulders and under the arms, and fastened across their breast. When they had deposited the wood at the storehouse, they departed to their respective homes. . . . Though we had numbered, in our journey to-day, 600 houses, we had not seen anything like four hundred people, almost the whole population being employed in the mountains cutting sandal wood."

Such unjustly hard labor, for which the common people received little gain, was naturally irksome to them. It is said that during their trips into the mountains, they would surreptitiously destroy many seedling trees to prevent their growth to marketable size. They realized that the fewer sandalwood trees existed, the lighter would be their future toil in cutting them down and carrying the heavy logs to the coast. This is in sharp contrast to the practice of Kamehameha the Great, a score of years earlier, who stringently prevented the cutting of the smaller trees, observing that such wood was to be preserved for his successors.

As early as 1816, Kamehameha bought a vessel called the "Forester" from a Captain Piggott. Its name was changed to "Kaahumanu," in honor of his favorite queen, and in March of the following year it sailed for Canton, laden with sandalwood. Instead of returning filled with Chinese goods, the "Kaahumanu" arrived nearly empty and in debt for \$3,000. The failure of this first Hawaiian trading enterprise, according to the captain, was that some of the money from the sale of the sandalwood had been stolen and that the Chinese had demanded exorbitant port charges and fees for pilotage. From that time on, port charges were collected from vessels visiting the Hawaiian Islands.

The disastrous end of the sandalwood industry conducted by the Hawaiians is connected with the enterprising High Chief Boki.*

* The missionaries represented the sounds of the Hawaiian language by the letters a, e, i, o, u, h, k, l, m, n, p and w only. In general, these letters were pronounced as in German or Spanish. K was sometimes interchanged with t, and l with r due to the fact that the Hawaiian language really had two sounds, one being intermediate between each of these pairs of consonants. In the speech of the natives on some islands these two sounds approached k and l, while on the remaining islands they approached t and r. Only after the unification of the Hawaiian Islands under the rule of Kamehameha I did the language become more uniform. The absence of the letter h in the Hawaiian language yet its presence in the name of a Hawaiian chief needs explaining: Kahikili, an enemy of Kamehameha, owned several dogs trained to attack men. These he had procured from foreign ships. While one of these English dogs, answering to the name of Boki, was at its height of fame among the natives for its exploits in battle, the chief was born. He was accordingly named in honor of the dog.

He accompanied Liholiho, or Kamehameha II, with Queen Kamamalu to England in 1824 where both died of the measles, and returned with their bodies to the Islands on the British frigate "Blonde," commanded by Lord George Byron, cousin of the poet. Upon his return, Boki was made Governor of Oahu. During the minority of Kamehameha III, Queen Kaahumanu, the widow of Kamehameha I, was Regent of the Kingdom. Within a few years after his return from England, Boki aspired to greater power than the governorship and even drew up an armed force at Waikiki to accomplish his ambition. He was fortunately persuaded, almost at the last minute, against causing a rebellion, and dismissed his troops. When he heard in November, 1829, that an island had been discovered in the South Pacific on which much sandalwood grew, his energies and ambition were diverted into fitting out an expedition for colonizing it and wiping out his debts by procuring the precious wood that had become locally scarce.

The man-of-war brig "Kamehameha" and a smaller vessel named "Becket" were selected for the undertaking. Each was well provided with arms and ammunition as well as with provisions desired for colonizing purposes. Against the advice and remonstrances of many Honolulu people, the two vessels sailed December 2, 1829, hastily equipped and insufficiently manned with skilled sailors. Almost 500 men had enlisted as soldiers, sailors and attendants. Among this number were some of the most energetic and venturesome Hawaiian youths and ten foreigners as navigators, some of the latter being utterly unscrupulous adventurers. On the "Kamehameha," commanded by Boki, about 300 men were crowded for the long voyage through the tropics. On the small 100 ton "Becket," commanded by Manuia, a trusted follower of Boki, the remaining 179 men were obliged to live. The expedition was first to stop at the small island of Rotuma, one of the New Hebrides north of Fiji, before continuing to the larger sandalwood island called Eromanga.

Boki in his vessel arrived at Rotuma first. He treated the natives of the island with harshness, forcing them to cut sandalwood for him, while his companions became discontented due to the hardships of the undertaking. After completing his preparations on Rotuma, Boki and his followers set out for Eromanga, which was distant but a few days' sail. From that day on, no sign of the "Kamehameha" or of the 300 men has ever been seen.

All perished. It is probable that either the powder was accidentally ignited by a careless smoker and the vessel blown to pieces with all on board, or that she struck some unknown reef and foundered. The "Becket," on the other hand, arrived at Rotuma Island ten days after the "Kamehameha" had left it, and, not finding her there, sailed on to Eromanga to meet her. Here Manuia and his followers waited in vain for the "Kamehameha," whose fate could only be conjectured, and committed various outrages on the natives which lead to frequent hostilities. At length a disease broke out among the voyagers of which many died, including the commander, Manuia. After a five weeks' stay on Eromanga, during which nothing was accomplished, all but a few of the survivors set sail to return to Oahu. In addition, forty-seven natives from Rotuma embarked as passengers. Crowded with the sick and the dying, the "Becket" slowly crept toward home. Due to lack of medicines and insufficient food and water, the wake of the vessel was strewn with corpses. Finally, crazed by the agonies of famine and thirst, it is reported that the stronger cast the dying as well as the dead overboard. On August 3, 1830, the "Becket" arrived in Honolulu with only twenty survivors, and of these, eight were foreigners. Thus ended the sandalwood expedition as a national disaster. A desultory trade in Hawaiian sandalwood lasted about ten years longer, when it ceased entirely with the forests despoiled of nearly every tree.

HAWAIIAN MISTLETOE, HULUMOA OR KAUMAHANA

The Hawaiian Mistletoe (Plate 35), known as *hulumoa* or *kau-mahana* to the natives, belongs to the *Loranthaceae* or Mistletoe Family, a family apparently derived from the one to which the sandalwood belongs. Some excellent specimens may be seen most conveniently in the Bird Park, or Kipuka Puaulu, a few miles from Kilauea Crater on the Island of Hawaii. The herb is rather interesting, as it shows us what has happened to a race of plants like the sandalwood as a result of concentrating on a parasitic means of existence.

The sandalwood, as described in the preceding pages, usually robs neighboring plants of some of their food by means of sucking organs, or haustoria, attached to the roots. The mistletoe has gone a step farther. It is a plant whose roots have degenerated to such an extent that nothing remains excepting one highly developed haustorium. This is attached not to the roots of its host,

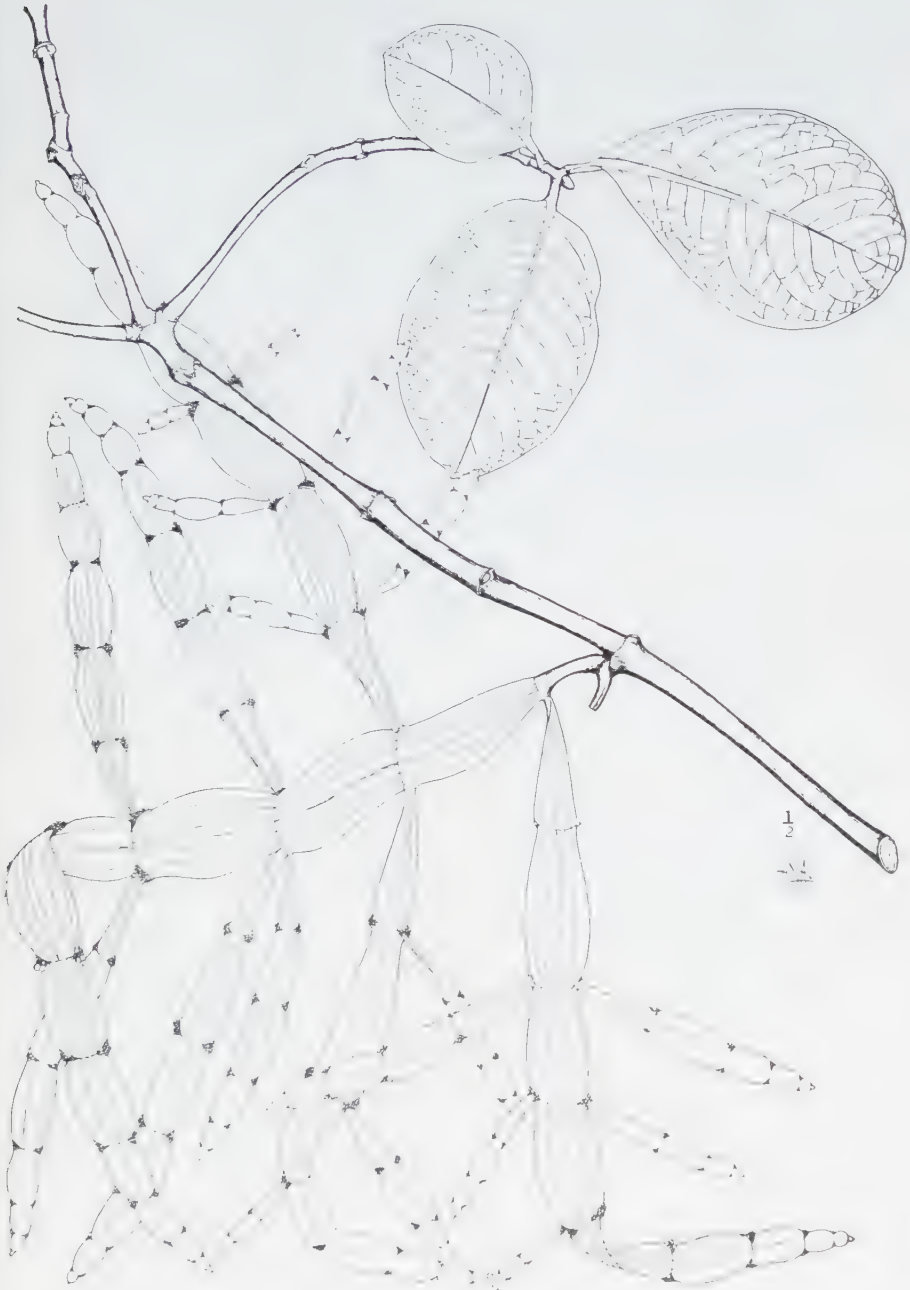


PLATE 35.—Hawaiian Mistletoe or Hulumoa parasitic on *Straussia* branch. (Original.)

but to one of its branches. In addition to the loss of its roots, the mistletoe has lost its leaves, though the nodes where they once were borne are still visible as joints. The leaves have gradually dwindled away from generation to generation for two chief reasons. They expose too much surface to the drying influence of the air for plants which gain a comparatively meager supply of moisture from their hosts. They have become superfluous, for in addition to the nourishment which is derived from the host, the stem by flattening out and exposing more surface to the light, has taken over their manufacture of plant food. The result of such changes is the cactus-shaped mistletoe figured on Plate 35.

The mistletoe bears distinct pistillate, or "female," flowers and staminate, or "male," flowers in minute clusters at the joints, or nodes. After pollination has occurred, the pistillate flowers develop into small globular fruits that are eaten by certain birds. After their meal, these scatter the sticky seeds, without design, from tree to tree. Provided the seeds have reached a plant that is suitable as host, the growing seedling bores into the bark for nourishment and then, finally, produces its green, jointed branches. These parasites are, of course, injurious to the host upon which they feed, but seldom cause its death as that would involve their own.

Not all the mistletoes in the Hawaiian Islands are of the same shape nor do all grow on the same kind of host. Some have extremely flat branches, while others have them almost round. Some are found growing on a plant called *Straussia*, as the upper part of the plate clearly shows; others, for example, grow on *Elaeo-carpus*. How many of these differently shaped mistletoes owe their characteristics to the type of juice they absorb, from one host or from another, is not yet definitely known. Nor are we sure on how many different kinds of trees and shrubs a certain mistletoe can live. We do know, however, that the Hawaiian plants belong to the group called *Viscum*. It is not within the province of this Guide but in that of the Flora to discuss the correct name of each kind of Hawaiian mistletoe.

RUMEX OR DOCK

About one hundred fifty kinds of dock or sorrel, known scientifically as *Rumex*, are found throughout the world. All belong to the *Polygonaceae* or Buckwheat Family. Five or six of these may be seen in various parts of the Hawaiian Islands.



PLATE 36.—Hawaiian Dock or Pawale. (Original).
Enlargement of fruit and of pistillate flower.

The sheep sorrel, *Rumex acetosella* L., may be found along the roadside, particularly near the Military Camp in the Kilauea Section of the Park. It grows also within Haleakala Crater on the Island of Maui. The seeds of this plant were, no doubt, accidentally introduced from Europe by way of America, probably in fodder imported for cattle. This sorrel may be distinguished easily from other kinds of *Rumex* because its "male," or staminate, flowers and its "female," or pistillate, flowers are borne on separate plants. It also differs in being small, rarely exceeding one foot in height, and in possessing spear-shaped leaves of pleasantly sour taste. These can be cooked and eaten like spinach.

Rumex giganteus Ait., (Plate 36), the *paʻuale* of the Hawaiians, and its varieties are native to these islands. Plants may be found growing on the inner slopes of Haleakala Crater, in the Crater of Kilauea and notably in Kilauea-Iki. They grow well in the crevices of cliffs and on extremely arid and barren lava flows where few other plants are able to gain a foothold. In such places they are stocky, upright shrubs several feet in height. In the wet forests in the District of Kōhala on the Island of Hawaii, some plants have been found with stems thirty feet long clambering over bushes and small trees in a way that is reminiscent of the climbing grapes of the Eastern United States.

It is probable that the Hawaiians in the early days used the *paʻuale* as a remedy for some skin disease common to these islands. Then when leprosy gained entrance here around 1840 with the return of a native chief who had contracted the disease abroad, the Hawaiians employed this same medicine as an alleged specific against that malady. It was prepared by taking the clean bark, stripped from the root, and boiling it for about four hours. This was then mixed with *awa* (p. 122) and administered to the leper in small doses. This boiling was accomplished in the typical Hawaiian way. As the natives possessed neither earthenware nor metal dishes but only wooden ones or calabashes, both of which are inflammable as well as poor conductors of heat, they naturally did not expose them to the fire. Instead, they would drop clean, red-hot stones into the liquid contained in the vessel to bring it to a boil.

The Curly Dock, *Rumex crispus* L. (Plate 37), grows along the roadside near the Hilo entrance to Hawaii National Park. This plant, like the sorrel, has been accidentally introduced into these islands. It is conspicuous because of its slender flower stalks

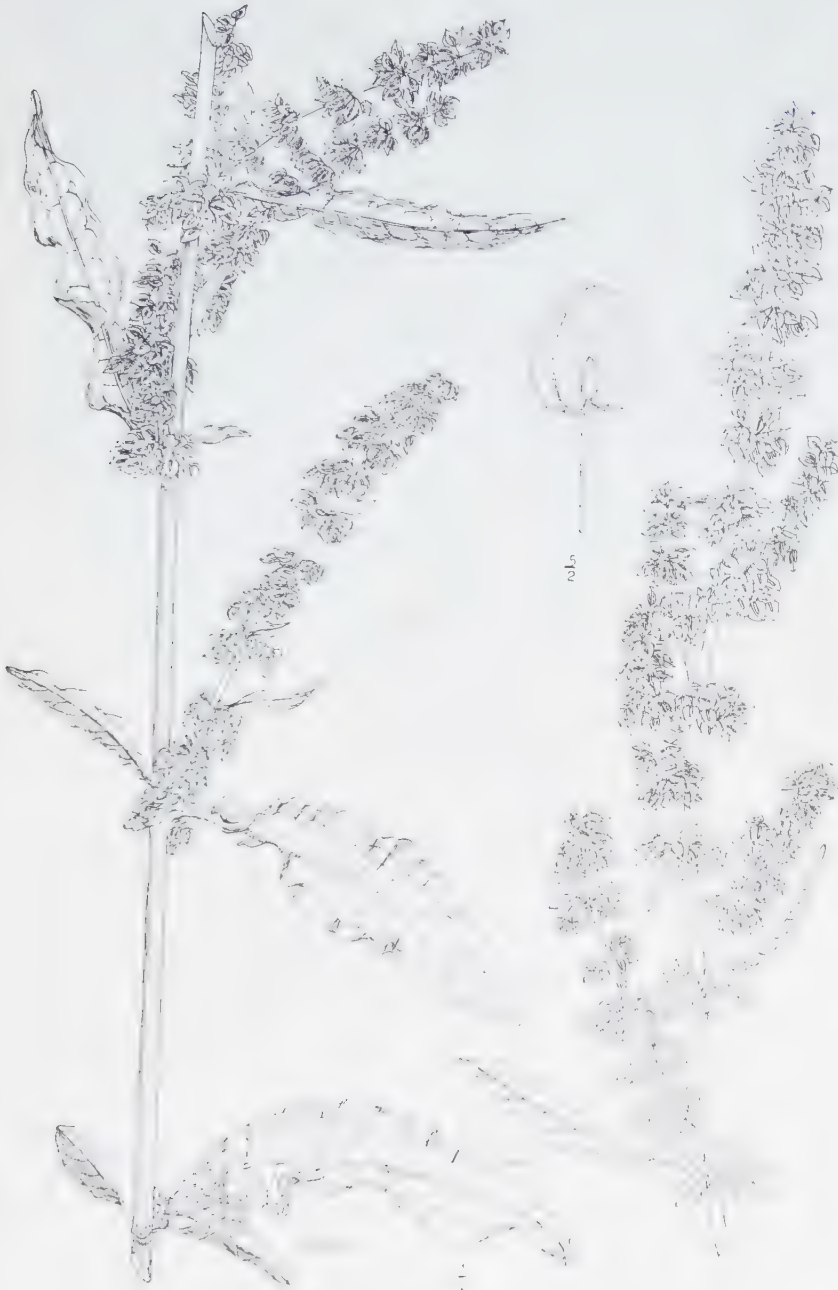


PLATE 37.—Curly Dock. (Original).
Enlargement of fruit.

that become one to four feet tall. The plant can be readily distinguished from all others by the crisped or wavy margins of its oblong leaves, as the plate clearly shows.

The flowers of *Rumex* bear no petals, but instead have six inconspicuous sepals arranged in two whorls of three each. The single large seed that forms in the ripening pistil never leaves the latter. The pistil merely dries around it, furnishing it with an additional protective covering. In the sorrel, the sepals do not enlarge as the seed matures. The plant, consequently, has no special method for dissemination. In the giant dock peculiar to these islands, however, the inner sepals develop into wings that completely hide the seed from view, as the enlarged figure at the left of Plate 36 will show. The resulting structure, called botanically a fruit, is now adapted for distribution by the wind, probably rolling over the ground for a considerable distance before lodging in some crevice where the seed may germinate. The fruits of the curly dock are still more highly specialized for distribution. Each of the three inner sepals not only grows into a wing, as in the case of the Hawaiian plant, but develops a cork-like swelling at its base. This is clearly shown in the corresponding figure of Plate 37. Now if the wind should carry the fruit into a stream or lake, it will not sink to die at the bottom but will most likely drift ashore where its central seed can germinate and produce a new plant. Some foreign kinds of *Rumex* have even developed hooks upon their fruits, thus enabling the seeds not only to be disseminated by wind and by water, but by animals in whose fur the hooks may catch.

SILENE OR CATCHFLY

About 250 kinds of silene or catchfly grow throughout the world, more than half a dozen being found in the Hawaiian Islands. All comprise the group known as *Silene*, belonging to the *Caryophyllaceae* or Pink Family.

Silene struthioloides A. Gray and its variety are catchflies typical of the volcanic regions on Hawaii and Maui only. They grow in ash and in cinders where no other plant except the silver-sword (p. 306) can thrive. In the Kilauea Section of the Park, the plants may be found in considerable numbers between Keanakakoi Crater and Halemaumau, while an occasional one may be observed near Uwekahuna Observatory and elsewhere. In the Haleakala



PLATE 38.—*Silene* or Catchfly. (Original).

Section, they are most numerous in the bottom of the crater near the cinder cones.

This silene, growing in extremely arid ground usually more or less impregnated with salts, has been obliged to curtail its requirements for water. It has accomplished this by reducing the number and size of its leaves, organs through which most of the water within a plant is given off. Consequently, the plants near Kilauea resemble dead twigs, one to three feet high. Closer examination, however, shows that they are alive, bearing awl-shaped leaves toward their ends and sometimes clusters of pale flowers that open only at night. The Haleakala plants, one of which is here figured (Plate 38), have a slightly different aspect, being low and extremely compact in form.

The silene are called catchflies because the stems of most kinds bear hairs that exude a sticky substance by which insects, attempting to crawl to the flower for nectar, are caught. In this way, the plants prevent unnecessary waste of pollen and reserve it for other visitors. Insects crawling from one flower probably would drop most of the pollen adhering to them before reaching another flower. In the case of flying insects, like moths, no such loss would occur.

BUTTERCUPS

The *Ranunculaceae* or Crowfoot Family is typical of temperate and cold regions of the northern hemisphere. When any of its members are native to the tropics they usually grow at considerable elevations where the temperature is low. Thus in these islands only two native members of the Crowfoot Family are known and neither one has been collected below an elevation of 2,000 feet. Moreover, two members of recent, accidental introduction grow above 3,000 feet. All these plants, curiously enough, are buttercups, known botanically as *Ranunculus*.

The Maui buttercup, *Ranunculus mauiensis* A. Gray, is found on all the larger islands of the group, being especially numerous in the Kokee region of Kauai. It has not yet been collected within the boundaries of the National Park.

The Hawaii buttercup, *R. hawaiiensis* A. Gray, here shown (Plate 39), is limited to the Island of Hawaii and to the eastern part of the Island of Maui. It has not yet been found in the Kilauea Section of the Park but may be seen on the moister grassy slopes of Haleakala as well as within the crater near Koo-



PLATE 39.—Hawaii Buttercup or Makou. (Original).



PLATE 40.—Spiny-Fruited Buttercup. (Original).

lau Gap. It is an erect, coarsely hairy herb, two to four feet high, having a hollow stem. The leaves are divided into three segments and each of these, in turn, has the tendency to split again into three more. The flowers are terminal, yellow, and rather small.

The creeping buttercup, *R. repens* L., a native of Europe and possibly of western North America, was accidentally introduced, probably in impure vegetable seed, shortly before 1922 near the Kilauea Section of the Park. Within eight years it has overrun large patches of ground not far from the Hilo entrance. This weed may thus become a part of the Park's introduced flora in the future. The plant may be recognized by its extensively creeping habit, bright yellow flowers almost one inch in diameter, and three-divided leaves marked with light green areas.

The spiny-fruited buttercup, *R. muricatus* L., (Plate 40), is native of Eurasia but has become extensively naturalized in North America. In these islands it was first discovered in 1922 growing in pastures not far from the Hilo entrance of the National Park. By 1930 it had spread extensively and was growing in large patches in the Bird Park, or Kipuka Puau. This plant likewise is of accidental introduction. It is an upright, hollow-stemmed herb becoming two to three feet high. It bears small flowers which, upon further development, produce seed-like fruits differing from those of all the other buttercups found in the Islands by being beset with small spines.

The buttercups are interesting representatives of rather primitive flowering plants. By studying them and their still simpler relatives, one gains a clue to the general way in which true flowers have evolved in the Plant Kingdom. A flower is, apparently, the greatly shortened upper part of a branch which in former ages bore an indefinite number of highly modified leaves in spiral arrangement. Those toward the apex originally bore ovules, or unfertilized and undeveloped seeds, freely exposed to danger. They were attached to the margins of the leaves in a manner very similar to that observed in the leaves called megasporophylls (Fig. 34, A) found in the "female" cycad or "sago palm" planted in gardens in the Hawaiian Islands and in other warm countries. Such a structure would correspond to an opened pea pod in which the peas, or ovules, have been turned to lie beyond the two margins (B). Though no irrefutable proof is at hand, it is the belief that such ovules finally bent in for protection toward the upper surface of the leaf to lie just within its margins. There upon the two halves of the leaf folded together along the midrib.

The resulting structure was called a carpel (C) and closely resembled the pod of a pea with its enclosed seeds. To derive the one-seeded carpel of the buttercup (D), we must imagine that the pod had decreased in size and that the number of ovules within had been reduced to a single one.

Below the series of carpels (Fig. 34, E) the hypothetical stem bore numerous leaves, each bearing pollen-producing anthers. These leaves, obviously, are today represented by the stamens. In the buttercups, there is considerable evidence to indicate that some of the lowest stamens flattened out and became colored petals. In many other types of plants, on the contrary, leaves below the

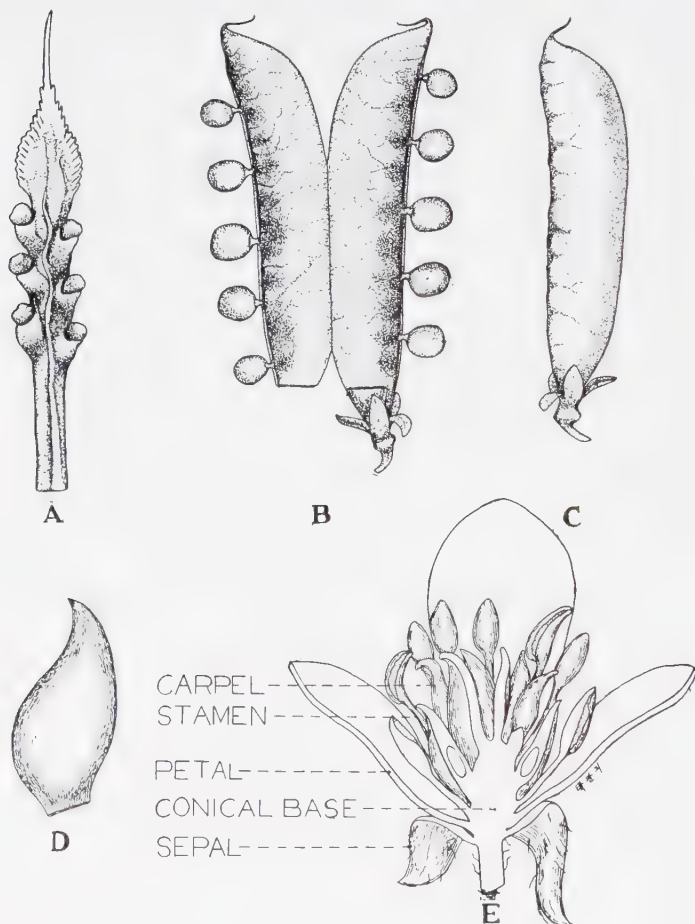


FIGURE 34.—Hypothetical series illustrating evolution of a carpel from a megasporophyll, and diagram of buttercup flower. (Original).

staminate ones, by becoming showy, developed into petals. Petals, consequently, are not homologous structures in all kinds of flowers; some are modified stamens, while others are merely colored leaves that never passed through a staminal stage in their evolution.

Below the petals comes a series of leaves that are the least modified of all. They are called sepals. They are usually green and protect the more delicate parts of the flower above them.

In comparing the buttercup flower with the hypothetical shoot mentioned above, we observe that the individual parts of the former are arranged spirally on a steeply conical base, as the longitudinal section of the flower shows (Fig. 34, E). This is to be expected in an organ that stands at a comparatively low stage of evolutionary development. The floral parts are spirally and not cyclically arranged as in more highly evolved flowers, because a spiral arrangement is the primitive position of leaves on a stem. And the common base of the floral parts of the buttercup is conical and not flat as in more highly evolved plants, because the stem bearing these structures has not yet shortened to a flat disk—the stage beyond which it can shorten no more.

The different members of the buttercup flower vary considerably in number, even in flowers on the same plant. This also is a primitive feature. This shows that the flower has not yet become stereotyped in structure. Its floral leaves vary in number on its shortened stem just as foliage leaves may vary in number on a sterile shoot of a certain definite age.

The carpels in the buttercup are numerous and distinct, while in the flowers of most other plants they are not only reduced in number but the few remaining ones have usually grown together so that their individuality is not apparent without dissection.

The native buttercups were apparently of no special use to the Hawaiians. They were known as *makou*, or less commonly as *avakana'aloa*.

CASSYTHA OR KAUNOA PEHU

Some extinct member of the Sandalwood Family by concentrating on a parasitic means of existence gave rise to the mistletoe, as previously described (p. 148). Some extinct member of the Morning-Glory Family, by becoming parasitic gave rise to the dodders, of which two kinds are native to the Islands though

not found in the Park. An extinct member of the *Lauraceae* or Laurel Family, in a similar manner, evolved into *Cassytha*, parasites that are considered by some botanists to constitute a family of their own known as the *Cassythaceae* or Love-Vine Family.

One of the representatives of this parasitic group of plants is *Cassytha filiformis* L., or *kaunoa pchu*, a native of the Hawaiian Islands as well as most tropical countries. The plant prefers dry, hot districts and therefore does not grow here above an elevation of a few thousand feet. Within the boundaries of the Park it can be found only on the lava plains adjoining the sea south of Kilauea Crater. A striking station for this plant, easily observed by Park visitors driving around the Island of Hawaii, is the *aa* lava flow that crosses the government road about five miles south of the old Pahala sisal plantation. Here the plants can be seen in their best development.

The cassytha (Plate 41) is a rootless vine devoid of foliage. Its leaves have degenerated into useless scales and no longer function to manufacture plant food. Instead, the slender branches sink haustoria or sucking organs into neighboring shrubs such as the lantana, the guava and the plectronia, to rob them of food. It sometimes happens that one branch of a cassytha may sink its haustoria into another, as the enlargement shows, so that the individual plant may be parasitic on itself as well as on other kinds of plants. The cassytha often covers its host with so many of its slender thread-like branches that the host may appear covered with a coarse, green fish net.

That cassytha is closely related to the *Lauraceae* or Laurel Family, if not actually a member of it, is apparent on comparing its flowers with those of the avocado, a typical representative of that family. The stamens of the cassytha even dehisce in the same peculiar way by means of minute valves which open from below upwards. The fruit of the cassytha is a spherical structure consisting of the ripened ovary surrounded by the fleshy, united bases of sepals and petals. These fruits are probably eaten by birds which aid in the dissemination of the plant.

The cassytha must not be confused with the dodder, an entirely different plant. Both parasites superficially resemble each other because both have perfected themselves for the same unusual mode of existence. In flower structure they are strikingly different. For the casual observer, the cassytha can be distin-



PLATE 41.—*Cassytha* or *Kaunoa Pehu* parasitic on *Lantana*. (Original).

guished from the dodder by having green branches tinged with yellow or orange. Those of the dodder are yellow without even the slightest shade of green.

HAWAIIAN POPPY OR PUAKALA

When Captain Cook reached the Island of Hawaii in 1779, he noticed a conspicuous herb belonging to the *Papaveraceae* or Poppy Family growing in the lowlands, especially in very dry localities. This plant was called by the natives *puakala*, *pua* meaning "flower" and *kala*, "thorny." Later the settlers, and even most botanists, named it the Mexican poppy, mistaking it for a plant with yellow petals native to tropical America. This was an unfortunate error as the *puakala* is peculiar to the Hawaiian Islands, having, however, a close relative native to Florida and a more distant one native to Colorado. Instead of continuing to call the plant by an inappropriate name, it should be known henceforth either by the Hawaiian name of *puakala*, by the corrected English name of Hawaiian poppy,* or, as soon as published in the *Flora Hawaiiensis*, by the scientific name of *Argemone glauca*.

The *puakala* is a striking herb (Plate 42), two to five feet tall. Its stem and leaves are densely beset with prickles that are so sharp that both man and beast avoid touching them. The plant is also covered with microscopic granules of wax that impart a powdery appearance or bloom. This hinders evaporation and thus aids the plant in growing in dry regions. The flower buds are also beset with prickles and covered with this bloom. When they are about to open, the sepals do not spread apart as in other plants. They remain united and are torn from their base by the swelling petals. As these unfold to attract insects by their brilliant whiteness, the hood-shaped sepals fall to the ground.

Like all members of the Poppy Family, the *puakala* contains abundant milky juice of yellowish color. This probably harbors many of the narcotics found in the juice of the opium poppy. It speaks well for the medical lore of the early Hawaiians that they were accustomed to use this plant to deaden the pain from toothache, thus practicing in a crude way the refined medication of the dentist of today. The natives merely pounded the rind of the plant, heated it and then placed it on the aching tooth. To remove

* According to the recommendation of the American Joint Committee on Horticultural Nomenclature in Standardized Plant Names, 1924, the common name for *Argemone* should be pricklepoppy. But here that name has been displaced by the simpler *poppy* for the sake of euphony, no danger existing as to what plant is implied, as no other native member of the Poppy Family exists.

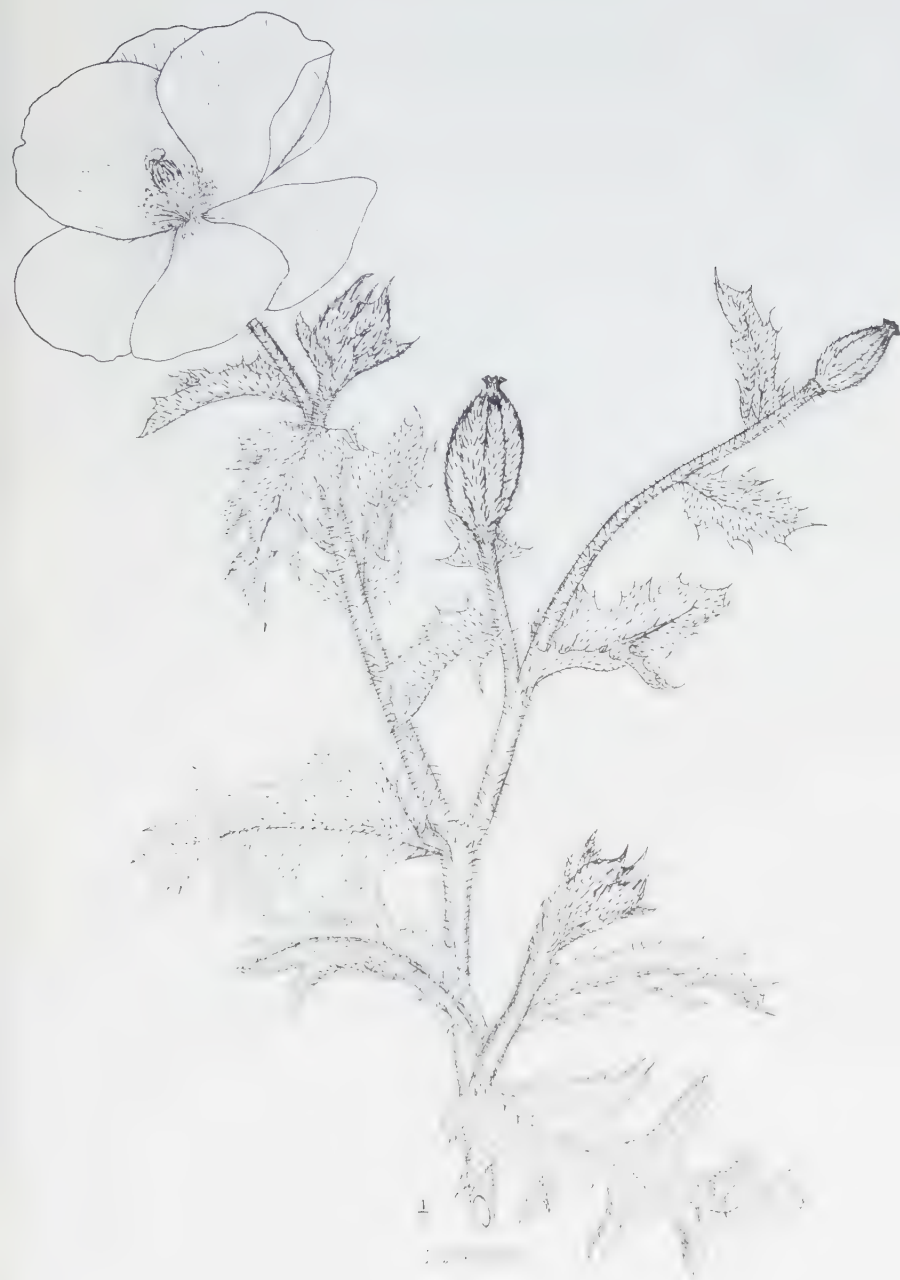


PLATE 42.—Hawaiian Poppy or Puakala. (Original).

warts, the juice of the stem was placed upon such growth and exposed to the sun. As soon as the juice had dried a second application was made and allowed to dry. This was repeated several times with the result, it was said, that the wart finally sloughed away.

BROUSSAISIA OR PUAHANUI

The broussaisia, known by some Hawaiians as *puahanui*, and by others as *kanawao*, belong to the *Saxifragaceae* or Saxifrage Family. Only two kinds are known and both are found exclusively in the Hawaiian Islands, where they thrive in wet forests. They are usually small, shrubby trees with thick branches hairy toward their ends. The two kinds can be readily distinguished from one another. *Broussaisia arguta* Gaud., has its leaves in opposite arrangement on the stem while *B. pellucida* Gaud., as the accompanying drawing (Plate 43) of leaves and leaf scars shows, has them in whorls of three each. The latter plant is rather common in the denser forest of the Kilauea Section of the Park.

The broussaisia exhibit two general principles that find expression in many plants. Namely, they have condensed their flowers into compact clusters, and they have made their flowers unisexual.

The broussaisia bear small, inconspicuous flowers. If these were to stand alone in the axils of the leaves, they would be rarely noticed by insects, and those insects that might notice them would be seldom induced to visit them for the small quantity of nectar secreted. Thus the plants would lose many opportunities of having their flowers cross-pollinated to insure the production of seed. To make up for such a defect, the flowers are massed together into large, terminal clusters, which, by sheer size and position, command attention. Insects, especially flower beetles and wasps, now visit them and with ease satisfy their hunger with the nectar secreted in a single cluster.

In the broussaisia we have plants that are just on the point of perfecting their flowers into unisexual structures. In studying them, therefore, we solve the mystery as to how the unisexual flowers originated in *Freycinetia* (p. 51), in *Coprosma* (p. 280) and in many other plants. The broussaisia plant depicted, bears only staminate, or "male," flowers. These consist of five minute sepals, five whitish petals often tinged with red, ten well-developed stamens and one degenerate pistil in the very center.



PLATE 43.—*Broussaia* or *Puahani*. (Original).
 Staminate, or "male," plant; 2 staminate flowers; 1 old pistillate, or "female," flower;
 fruit in cross-section to show seed

The latter never produces any seed and is apparently of no value to the plant. It is a worthless relic of the past that shows that one and the same flower in the broussaisia of early times produced seeds as well as pollen. In future ages the staminate flowers of these plants will probably lose their degenerate pistil entirely. Of the present broussaisia, the pistillate flowers, one of which may be seen illustrated at the right of the plate, in contrast to the staminate, have apparently already reached perfection. They possess well-developed pistils but lack even rudimentary stamens. From this we can safely conclude that unisexuality in flowers in most cases has originated by the progressive abortion of one of the two sex organs originally borne within them.

UULEI

The *uulei* (Plate 44) of the Hawaiians is *Ostcomeles anthylli-difolia* (Smith) Lindl. It is a member of the *Rosaceae* or Rose Family and not far removed in relationship from the hawthorn and the common apple. The plant is peculiar to the Hawaiian Islands, where it grows in the drier regions below an elevation of about 4,000 feet. It is one of the more common plants of the Kilauea Section of the Park.

The *uulei* is a woody plant with compound leaves and clustered, white flowers resembling those of the apple. These at length develop into small, whitish, somewhat sweet fruits, each containing five stones. Usually the plant is a straggling, much-branched shrub creeping over the ground or rising to a height of a foot or two. But in the *aa* (Fig. 9) lava flows along the government road in the districts of Kau and Kona, Island of Hawaii, the plants develop into trees a dozen feet high.

The *uulei* has very strong but pliable wood. Its long branches were therefore stripped of their bark and tied to the rims of fish nets, acting like a hoop to keep them open. In this way, for example, the Hawaiians constructed their nets for catching the *opelu*, a fish that swims in schools and is a favorite for eating raw either when freshly caught or after it has been dried in the sun. A net about twenty-five feet long was prepared by sewing it in the form of a huge bag. To the upper rim of the wide mouth a series of long, slender branches of the *uulei* were fastened to keep it gaping. This was then lowered on ropes in moderately deep water by the fishermen in their outrigger canoes. In the meantime, grated taro had been cooked and tied in *kapa* (p. 132). This



PLATE 4. *Uncaria* (Original).

was then lowered as bait on a string into the sea so as to hang midway between the surface and the bottom. When a school of *opelu* had been attracted by the taro, the net which had been hanging below the bait, was carefully raised toward the surface. The enclosed fish, made frantic with fright when one of the fishermen would perhaps jump in among them, would dart in all directions and be caught by their gills in the meshes of the net.

HAWAIIAN RASPBERRY OR AKALA AND RELATED PLANTS

No one knows how many different kinds of blackberries, dewberries and raspberries exist in the world. Some authorities have estimated that there are about two hundred, while others maintain that more than twice that number occur. This uncertainty is due to the fact that many kinds are extremely variable and that some readily produce hybrids with others, and that these hybrids may or may not resemble their parents closely. The student gathering a specimen, therefore, can not be sure whether he has found a hybrid, a new kind of plant, or an unusual variation of a plant already well known. All botanists, however, are agreed that these plants belong to a single group, named *Rubus*, which belongs to the *Rosaceae* or Rose Family.

A blackberry, introduced into these islands from continental America before 1900, has escaped from cultivation and may now be found on western Oahu, on Maui along the Olinda Pipe-Line Trail just below the Haleakala Section of the Park, and on Hawaii in the vicinity of Kilauea. The plant has white flowers like most kinds of *Rubus*. It grows in the cool, open forest and is yearly becoming more numerous. Though producing an abundance of palatable black fruit in summer, these thorny shrubs should be hindered as much as possible from spreading because of the indication that otherwise they may become obnoxious weeds.

Another introduced *Rubus* is the rose-leaved thimbleberry whose botanical name is *Rubus rosaeifolius* Smith, not *R. jamaicensis* as stated by previous writers. This plant is a native of the Orient but unfortunately has been introduced into almost all the larger islands of this group excepting Molokai. Like the blackberry it bears white flowers but, unlike it, it produces fruit throughout most of the year. It thrives from sea level to an elevation of 5,000 feet or more and is rather common in the forest and clearings around Kilauea. A disease of leaves and stems caused

by a microscopic fungus, however, killed a great number of the plants in 1916 and may continue to check the rapid increase of this plant in the future. The bright red fruit is edible but lacks the delicious flavor common to the fruit of many other kinds.

Two native raspberries, named *akala* by the Hawaiians, are found in these islands at higher altitudes. Both produce pink flowers and therefore can be differentiated at once from the introduced thimbleberry.

Macrae's raspberry or *akala*, *Rubus Macraci* A. Gray, is comparatively rare. It may be seen sprawling over the fog-drenched moss at the head of Koolau Gap, the most interesting spot botanically within Haleakala Crater. This plant produces enormous fruit but these are of little economic value to man because of their bitterness.

The upright Hawaiian raspberry or *akala*, known as *Rubus hawaiiensis* A. Gray, shown on Plate 45, is a perplexing plant. Along the Olinda Pipe-Line Trail on Haleakala, where it is very common, some of the plants bear prickles on their stems while others are entirely unarmed. In a third type, the prickles drop from the stems in a year or two. Apparently this raspberry is on the point of splitting up into two or more distinct kinds. It is conceivable that if one of these unarmed plants, for example, should in some way become isolated from the prickly ones and be able to reproduce, its offspring would in time evolve into a new kind of raspberry that would never bear prickles. Possibly this is now coming to pass. The stems of all the raspberries seen growing on isolated Molokai lack prickles. There was one exception, and this occurred on an abnormal sprout that had probably reverted to the ancestral armed condition characteristic of most of the plants on Maui. On the Island of Hawaii other variations may be noted. Some plants bear yellow fruit; the typical color of the fruit on that and all the other islands is a very dark red. Only a very few *akala* grow in the neighborhood of Kilauea, probably because the altitude is rather low for them.

The fruit of this Hawaiian raspberry, or *akala*, sometimes attain two inches in length. They are juicy but vary considerably in bitterness. This makes some of them unfit for food. They also possess slightly laxative qualities if eaten in great numbers. Because of the ability of these shrubs to flourish here and because of their unusually large, juicy fruit, Dr. Willis T. Pope of the Federal Experiment Station in Honolulu has been growing and



PLATE 45.—Hawaiian Raspberry or Akala. (Original).

hybridizing *Rubus hawaiiensis* with various raspberries native to North America since 1928. By this method a cross may be developed which should flourish in this climate, and at the same time bear fruit that is large and juicy like that of its native Hawaiian parent and yet possesses the delicate flavor of its continental one. Such an undertaking is by no means visionary. We owe the existence of most of our best fruits, vegetables and ornamentals to the success that rewarded the patient industry of horticulturists like Burbank and many others.

The Hawaiians in the early days no doubt ate the *akala* when on their infrequent trips into the cold and usually wet mountains. It is definitely known that they prepared a dye for their *kapa* (p. 132) from the juice of the fruit of the upright Hawaiian raspberry. They even manufactured *kapa* cloth of inferior, yet not poor, quality from the bark stripped from its stems and from those of its relative. *Kapa*, however, made from the bark of the *wauke* and *mamake* was superior.

KOA

There are several varieties and forms of the *koa* (Plate 46) varying in the shape of their flowers, leaves and pods. They are found exclusively in the Hawaiian Islands. Related plants, however, are found rather common in Australia where they are known as wattles. Botanically, our plant is known as *Acacia koa* A. Gray, and belongs to the *Leguminosae* or Pea Family.

The *koa* is one of the largest trees of the Islands, inhabiting usually the drier forests between an elevation of 1,000 and 6,000 feet. Many of the trees are over 70 feet high. Near the Kipuka Puau in the vicinity of Kilauea Crater stands a dying giant which in its prime had a height of 118 feet and a girth of 30 feet. The flowers of the *koa* are pale yellow, have five petals which are of equal size, and are massed into small, spherical clusters. The flower structure is therefore simple in comparison to the other legumes figured (Plates 47, 48, 49), the latter having petals of different sizes so as to protect the stamens and pistil from injury.

Though primitive in flower structure, the *koa* is highly evolved in leaf shape. The leaves are normally falcate, or sickle-shaped. But in searching diligently for seedlings and for water sprouts, one will usually find a second type of leaf, similar to the one shown near the bottom of the plate, which consists of a stalk bearing



PLATE 46.—Koa. (Original).
Single flower; pod, broken to show enclosed seed; single leaf of ancestral type.

about eight leaflets. The reason for the existence of these two types of leaf on the *koa* seems clear.

It is certain that the early ancestor of the *koa* habitually bore compound leaves, namely leaves consisting of a stalk, or petiole, and a certain number of leaflets. As time went on, the environment inhabited by this kind of plant became arid. In order to thrive under these changed conditions, the offspring of these plants were gradually obliged to reduce their leaf surface, thus conserving water which otherwise would be lost by evaporation. After living under these conditions for probably hundreds of thousands of generations, the plants retained only the round petiole of the leaf. When the climate became wetter again, these desert plants with reduced leaves were at a distinct disadvantage. Many, doubtless, became extinct, while others were stimulated to increase their leaf surface again to meet the changed conditions. Because they had long lost the ability normally to produce their old type of compound leaf again, the plants from generation to generation gradually flattened out their petioles to simulate true leaves. At the present day, these curiously modified plants are the Hawaiian *koa* with their strange sickle-shaped leaves, termed phyllodes. The seedling *koa* reverts to the normal leaf-character of its distant ancestors and produces compound leaves. Water sprouts and branches arising from injured areas on the mature trees likewise frequently revert to the ancestral condition. One may, by a little hunting for such a twig, find all gradations from a true, compound leaf to a perfect phyllode.

The Hawaiians made their calabashes, or *umcke*, from the *kou* tree and practically never from the *koa* because, according to a recent publication, it imparted a disagreeable flavor to food stored within it. For souvenirs, however, *umcke* are now commonly made of *koa* wood and then given a shiny polish which the ancient Hawaiians never attained. The Hawaiians did make use of the bark of the *koa*, however, as a dye for *kapa* (p. 137).

The *koa* was at times used for the timbers of grass houses (p. 268). Its prime importance, however, was in the making of canoes (Fig. 35) of which the Hawaiians had not only single kinds, *kaukahi*, but even double kinds, *kaulua*, which consisted of two canoes lashed together in a special way. Of these two fundamental types there were many modifications to suit special needs. They ranged, for example, from small, narrow, single canoes, the *kioloa*, well fitted for the use of one fisherman, and for racing, to

single or double canoes, the *peleleu*, used in war or for long voyages. The canoes small enough for one to six or eight men to handle were 10 to 20 feet long and very narrow, being scarcely twelve inches wide at the broadest part. They were about two feet deep. The war and travel canoes, in contrast, were usually about 50 feet long but some were 100 and even 150 feet long and had a depth of 6 to 12 and even 15 feet. Such canoes were 1 to 2 or more feet wide. All were invariably hollowed out from a single log. Some of the largest and most famous war canoes were made from the trunks of giant evergreens that had been carried by ocean currents and winds from the American coast to these shores.



FIGURE 35.—Hawaiians, dressed in *malo*, with outrigger canoes of which the nearer shows the two *iako* by which the outrigger, or *ama*, is fastened; Diamond Head in the distance.

Before making a canoe, the Hawaiians employed a *kahuna*, or priest, to offer prayers and sacrifices to Ku, the long-bearded god of canoe makers, that the work should be successful. Then the *kahuna* aided the men in selecting a suitable tree in the forest. This was laboriously felled with stone adzes (p. 217) and then roughly hewn into shape with the same tools. If the *clepio*

(*Chasiempis* sps.) or the native crow, *alala* (*Corvus hawaiiensis* Peale), were to settle on the log, this was considered an ill omen and work on it abandoned. Another tree was sought to take its place. If all went well, to the cry of "*I ku mau mau waa*," the shaped log was dragged with ropes of *hau* (p. 213) bark to the coast to be hollowed out further. Finally it was smoothed and polished by rubbing it with the *olai* or *kawae wae*, a piece of abrasive lava or coral. After all the work had been completed, and the canoe had returned from a preliminary excursion out to sea, the *kahuna* was again called to offer suitable prayers and to sacrifice a hog or, in case the canoe was to be of considerable importance, a man.

The part made from the *koa* trunk was the *waa*. To this a gunwale or rim, termed *moo*, six to eight inches high, was accurately fitted and sewed or fastened with wooden pegs. This was made of the more durable *ohia lehua* (p. 230) or of the yellow *ahakea* (*Bobea* sps.), so that the paddles might rub here without much damage to the canoe. Additional pieces of thin wood of *koa*, breadfruit (p. 124), true *kamani* (*Calophyllum inophyllum* L.), or *kukui* (p. 193) were attached to both ends of the canoe to deck them over for several feet. These formed a prow, *manu mua*, and a stern, *manu hope*, each rising at the extreme end to a height of about 15 inches.

As these round-bottomed canoes were very narrow compared to their width they always had an outrigger, or *ama*, attached to them to keep them from rolling over in rough water. This consisted typically of a piece of *hau* (p. 218) or *wiliwili* (*Erythrina monosperma* Gaud.) wood, both being almost as light as cork when dry. The *ama* was half to two-thirds the length of the canoe, round, slightly upcurved at the middle, and turned up at the ends. It rested on the water parallel with the canoe at a distance of five to ten feet. It was attached preferably by means of coconut husk fiber (p. 75) to the ends of two downwardly curving yokes, the *iako*, of light wood that, in turn, were fastened at the top to both sides of the canoe near the ends. The buoyancy of such an outrigger prevented the canoe from turning over toward it, while the weight of the outrigger and the two *iako* prevented the canoe from tipping in the opposite direction. These canoes were frequently furnished with sails made of pliable *hala* bracts (p. 49). Instead of being wide at the bottom as were

those of other races, these sails were wide at the top and narrow below.

The bodies, or *waa*, of the canoes were generally covered with a black paint made of the milky juice of a native *Euphorbia* relative mixed with the juice of the inner bark of the *kukui* root, the juice of the bud of the banana (p. 105), and charcoal derived from *hala* leaves. Thereafter, the wood was rubbed with oil derived from *kukui* kernels. To such a black body, the unpainted, usually yellow *moo* gave a pleasing contrast.

The paddles of the Hawaiians were usually of *koa*. These consisted of a rounded shaft 3 to 4 feet long, and a thin blade 12 to 18 inches long and 8 to 12 inches wide. They were held by one hand near the blade and by the other hand at the upper end of the shaft. The paddlers made rapid, regular strokes, first all on one side of the canoe and, at the giving of a signal, all on the other. At each stroke, they raised their heads erect and lifted one hand high to throw the paddle blade forward beside the canoe before dipping their blades into the water and sweeping them back in unison. Such a craft was steered by a common paddle, held by a man sitting in the stern. In double canoes, one steersman sat in each canoe.

In double canoes, the second canoe really took the place of the outrigger. For long voyages, as remarked before, each of these might be 100 to 150 feet long. Between them a curved platform, called *pola*, was built three to four feet above the surface of the water. This was covered and often shaded with mats. The paddlers sat in the canoes while the passengers remained on the *pola*. Such complicated rafts often carried chiefs and retainers to wait on them, priests with their idols, astrologers, and musicians for entertainment. Enough food was taken to last for many weeks; gourds filled with water and fresh coconuts provided drink. Livestock, consisting of pigs, dogs and chickens, was also carried along.

At times as many as fifteen such double canoes formed a fleet. During the day, as they sailed or paddled along, they spread in a broad line so as to increase the chance of seeing islands. At night the canoes kept close together to avoid separation. To return, for example, to the Island of Hawaii which had been visited previously, these bold navigators made use of an ingenious sextant. While in Hawaii they noted the exact height of the North Star above the horizon. A gourd calabash was taken and four holes drilled into

its sides at right angles to each other. The upper part of the calabash was then probably ground down carefully until, by applying the eye to one hole, the navigator could sight the North Star over the rim of the calabash above the hole on the opposite side. To make sure that the calabash was held level while sighting, it was filled with water to the height of all four holes. With such a sextant on hand, the voyagers most likely found Hawaii again on their return. They merely sailed northeast until they could sight the North Star through the hole made in their calabash. At that time they were on the correct degree of latitude for Hawaii. As they had been traveling northeast, they were certain that Hawaii lay to the west of them. By sailing west on the same latitude, they were sure to reach one of the Hawaiian Islands.

MAMANI

The tree known by the Hawaiian name of *mamani* (Plate 47) is botanically called *Edwardsia chrysophylla* Salisb., and is peculiar to the Hawaiian group. At present it is found on all the larger islands excepting Molokai and possibly Oahu. On the latter island, a few sickly trees were seen some years ago, that may now be dead. On the Island of Hawaii the visitor may see the *mamani* best in the Kipuka Puau, a few miles from Kilauea Crater, and in the aa (Fig. 9) lava desert near the Kau entrance of the National Park. Within Haleakala Crater on the Island of Maui there are a few trees near the northern wall and on the more grassy plains near Kaupo Gap. Most of these, unfortunately, were in a dying condition in 1927 due to native beetles (*Plagithmysus funebris* Sharp and *Proterhinus* sp.) that riddle their branches with galleries for their young. They were also being attacked by caterpillars and goats which eat their leaves. The trees are very rarely found in wet, shaded forests or in the lowlands, being particularly adapted to barren slopes and rugged lava flows in very arid regions between 3,000 and 9,000 feet elevation.

The *mamani* is usually a small tree, though in particularly favorable localities it may grow to a height of forty or more feet. It bears clusters of beautiful, golden yellow flowers (A). As each of these flowers becomes pollinated by insects that gather the secreted nectar, its pistil swells and develops into a woody pod, called legume. This bears four longitudinal wings, as the drawing (B) of its cross section shows, and may be more or less constricted otherwise (C). Within are borne extremely bitter seeds



PLATE 47.—Mamani. (Original).
A, flowers; B, cross-section of pod showing wings; C, pods; D, seed.

(D) that are either reddish or yellow in color. As these are heavier than sea water, they could not float from one island to another to disseminate the plant. But they could be readily transported the short distances between the various Hawaiian Islands by ocean currents while yet contained in their woody pods. Because of the structure of the flowers and of the pods, we know that the *mamani* belongs to the *Leguminosae* or Pea Family.

The leaves of the *mamani* are termed compound because they bear leaflets. These, when young, as well as the new shoots, are covered with silky hair. As the twigs mature, this hair, or pubescence, is sometimes lost, especially by plants inhabiting lower altitudes.

The native enemies of the *mamani* are the beetles and caterpillars mentioned above. Their injury does not endanger the existence of the plant, otherwise it would have been exterminated ages ago. Introduced enemies such as horses, cattle, and feral goats and pigs are the real menace to these plants and to the beautiful wild groves and forests in general. They eat all of the young seedlings except the root, which must die soon after the upper part is gone. They also eat as much of the leaves and green twigs as they can reach on the older trees. Few seedlings survive the ravages of these grazing animals to take the place of the old trees as they finally succumb to the usual dangers of old age. Thus such interesting Hawaiian forests become more and more depleted until there remains nothing but a monotonous turf-covered landscape, punctuated with an occasional decaying tree. Such a region has become economically valuable for the raising of livestock and for perchance a few crops, but spiritually it has become worse than worthless to lovers of Nature. Striking examples of this necessary advance of Civilization over Nature may be studied between Waimea and Honokaa and between Waimea and Kohala on the Island of Hawaii, as well as in numerous other regions on the other islands.

As no livestock is now tolerated within the National Park and the goats are diligently hunted and shot, these regions on Hawaii and Maui should forever remain a refuge for the native plants, as well as for the native animals, that now live within their boundaries. Neglect in strenuously pursuing this policy in the early days has resulted in irreparable loss to the Science of Botany by the virtual extermination of certain kinds of plants that would otherwise have been preserved. Many of the plants that are not

found within the Park nor in the extensive forest reserves are doomed to ultimate extinction. Since it is impossible to save them alive, the most practical plan to follow is to collect them now, while there is yet time, and to preserve them as herbarium specimens. Duplicates should be distributed to the various leading Herbaria and Botanic Gardens in America and Europe for study and safe keeping. It is certainly unwise to put all one's eggs in one basket, as then the loss of the entire collection, which could never be duplicated, might easily occur from accident or neglect.

The wood of the *mamani* is very hard and durable. It was used by the Hawaiians in the early days as a substitute for the more valuable and rarer *kauila* (p. 204) wood in the making of agricultural implements and adz handles. It was sometimes used for the posts and beams of their houses (p. 268). Often the sap wood of such timbers was carefully cut away, as that is not as strong and durable as the older, heart wood. During certain religious ceremonies to ward off evil, the high priest, or *kahuna nui*, would hold in his hand a piece of *mamani* or *kauila* wood wrapped in dark *kapa* (p. 132) as a symbol of his authority.

Mamani wood was preferred for the making of the runners of the Hawaiian sled, or *papa holua*. These sleds were often twelve feet long, having the runners spaced as little as two and a half inches apart at the base and about six inches apart at the top where the body of the rider was to lie. Before using, the runners were lubricated with the oil expressed from the kernel of the *kukui* nut. With these sleds the chiefs amused themselves by sliding at great speed down certain courses, about eighteen feet wide, that extended from a steep hill onto the plain below. These courses were first paved with flat rocks and then covered with earth that was beaten hard. A layer of dry grass, because of its slipperiness, was then laid on top.

In more recent times, the ranchers cut the trunks of the *mamani* trees into fence posts because of their great durability in the soil.

GORSE

The gorse (Plate 48), scientifically known as *Ulex europaeus* L., bears flowers and pods of essentially the same structure as those of the *mamani* (p. 179). Therefore it must belong to the same *Leguminosae* or Pea Family. It is not native to the Hawaiian Islands but to Europe, from where it was purposely introduced into the Island of Maui before 1901 by a homesteader. It



PLATE 48.—Gorse. (Original)

was planted by him as a hedge around his garden near Olinda to prevent sheep from gaining access. Within a decade, this dangerous weed has spread extensively over the western slope of Haleakala, making the pastures in which it becomes abundant absolutely impenetrable and worthless for grazing because of its sharp thorns which can inflict painful wounds. Much good has been accomplished by territorial prisoners who have been employed in eradicating and burning the plants. As the weed had time to spread extensively before this meritorious work was begun, sufficient plants will probably long remain to attract the attention of the visitor on the ascent of Haleakala from the Makawao side.

The gorse is a compact shrub four to six feet high, bearing numerous small branches that have been modified into sharp spines. These branches are green in color and thus aid the pointed, degenerate leaves in their proper function of manufacturing food to sustain life and promote growth of the plant. The flowers are bright yellow and add to the beauty of this odd and formidable weed.

The plant is disseminated in two important ways. Short branches bearing ripening pods become entangled in the tails of cattle and are carried considerable distances before the seeds are liberated and fall to the ground. Thus new clumps of plants may arise miles away from the parent plant. The usual method of distribution, however, is by the elastic mechanism of the pods that burst open with a clicking noise to hurl their seeds several yards in all directions. As each of these bears an oily, yellow appendage called elaiosome that is palatable to ants, these insects gather them and carry them to their subterranean nests. Here they can feed on the elaiosome at their leisure. Thus the seeds are effectively planted underground by ants which, in turn, are satisfactorily repaid in food for their labor.

PIGEON PEA

The pigeon pea (Plate 49), correctly known as *Cajanus cajan* (L.) Druce in scientific literature, is a member of the *Leguminosae* or Pea Family. As the plant has not been found in a truly wild state, its native home is not known with certainty. Various authorities, however, attribute its origin to Malaya, or to India, or even to tropical Africa. In Malayan the plant is called *katjang* and this word is the source of its scientific name.

The pigeon pea was undoubtedly introduced into the Islands

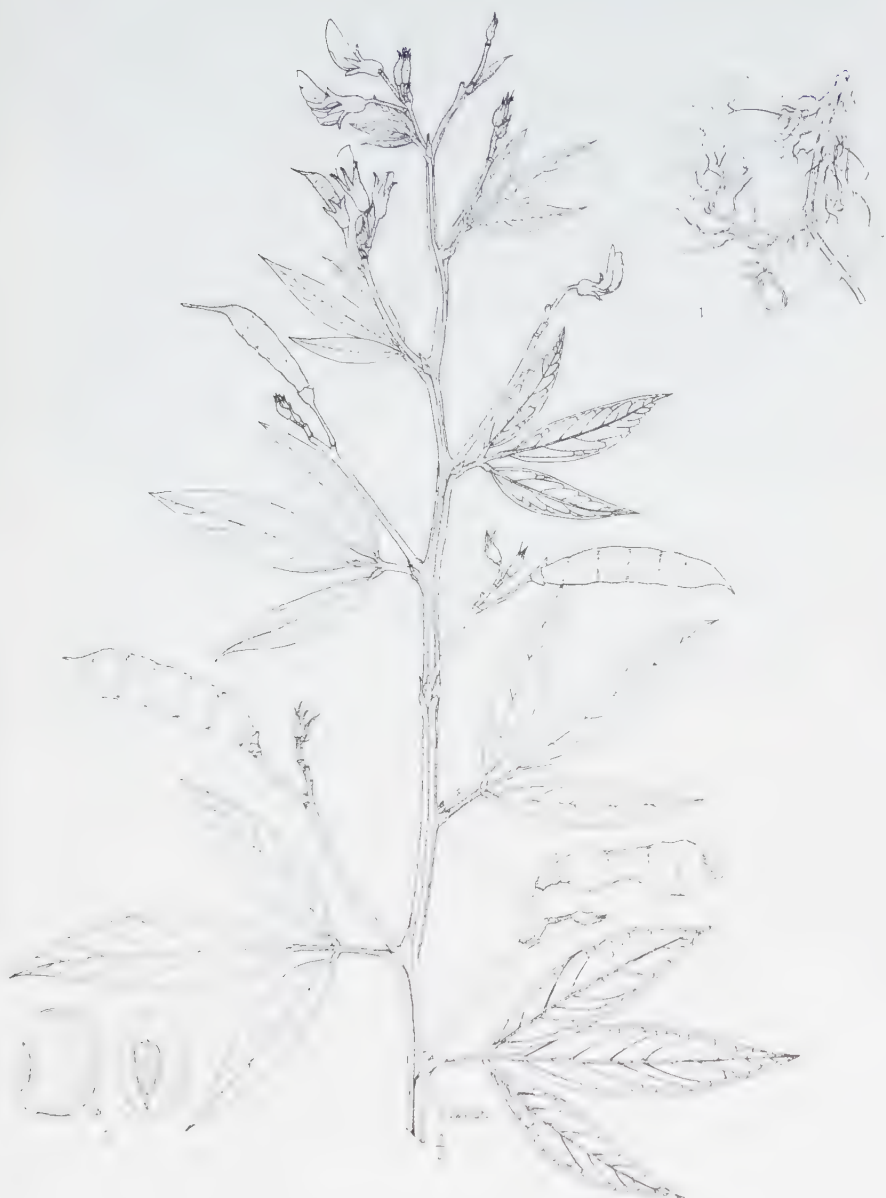


PLATE 49.—Pigeon Pea. (Original).

since their discovery by Captain Cook, yet no definite date is known for the introduction of this valuable plant. The earliest record that the writer has noted of its occurrence here is that of Horace Mann, the son of the famous educator, and William T. Brigham, the very versatile dean of Hawaiian scientists. As college students, they collected the plant as early as 1864 and at that time considered it "probably of aboriginal introduction." For the pigeon pea to have spread so extensively as to appear to them fully naturalized by 1864 would indicate that it had gained access to these islands at least a decade or two before.

The pigeon pea is a perennial shrub thriving in these islands up to an elevation of about 3,000 feet under rather dry or even semi-arid conditions. It has been found growing in a stunted state along the roadsides in the Kilauea Section of the Park, but never in wet localities. Normally, however, it grows to a height of four to ten or more feet. Its leaves are trifoliolate, namely composed of three leaflets attached to a common petiole or stalk. The flowers, borne in axillary clusters, are yellow to orange and often marked with brown or other colors. These flowers finally develop into compressed pods having diagonal depressions separating the seeds. The roots of this plant, like those of all members of the Pea Family, are remarkable. On freeing them of soil, one will see small swellings, or nodules (Plate 49, at right above), attached to them. These contain myriads of bacteria which are highly beneficial to the plant. They take the nitrogen from the atmosphere and change it into an available form, a process which flowering plants are unable to accomplish. The roots of the pigeon pea forthwith absorb the nitrogen. Thus the plant not only gains for its growth the little nitrogen usually procurable from the soil but even an additional supply from the atmosphere, a source lacking to other plants. If a field of pigeon peas is plowed under and allowed to decay, the crop planted in its stead benefits from the additional fertility the bacteria had originally taken from the air.

The seeds, when fresh and immature, can be eaten like green peas. Moreover, when they are old and have been freed of their leathery seed-coat, they form a substitute for lentils. They are also made into a sauce known as *dhal* and eaten curried. The plant has thus become the staff of life of five million people in India. In the Hawaiian Islands, however, the pigeon pea is valued not so much as human food but as forage for cattle and horses, as feed for poultry, and as a green manure for pineapples and other

crops. For these purposes the plant was first grown as a cultivated field crop in the Islands in 1906 by F. G. Krauss, then of the Federal Experiment Station, and first grown commercially by the same man at Haiku, at the base of Haleakala, in 1912. Previous to 1920 Prof. J. F. Rock introduced a new strain of the plant from Benares, India, and in 1928 Director Krauss, the pioneer grower, gathered numerous strains in many parts of the Orient. These were planted at the University of Hawaii and by 1930 about 500 different horticultural varieties and hybrids were growing there for experimental purposes under his direction. That year the estimated area covered by the pigeon pea throughout the Islands totalled 10,000 acres. About half of this was grown for fattening cattle and the remainder as a green manure for pineapples.

The visitor on his way to the Park will most likely observe extensive fields of this plant grown for stock feed. The seeds had been planted either in fall or preferably in spring in rows from four to five feet apart. Then when the plants are maturing their pods, six to eight months later, the cattle are usually turned into the enclosure to fatten. Here they browse on the pods, containing the seeds rich in nitrogen, and less eagerly on the leaves. As a green manure for pineapples, on the other hand, the pigeon peas are usually planted in rows spaced about two feet apart. Thus they are left for four to five years before being plowed under. Pineapples are then planted in their place and allowed to grow for an equal length of time. In this way many acres of otherwise useless land are being reclaimed for pineapple production.

HINAHINA

At higher elevations on the Islands of Kauai, Maui and Hawaii occur very strange plants, some of which are known as *hinahina* or *nohuanu* to the natives. These constitute a botanical group quite distinct from, yet related to the one to which the common geranium belongs. All these plants are members of the *Geraniceae* or Geranium Family.

The *hinahina* are small shrubs with the exception of one tree-like type which grows to a height of ten or more feet. Most of them bear leaves that resemble in shape the individual scales of a butterfly's wing. These leaves are usually densely covered with hair which imparts to them a beautiful silvery appearance. In one kind of *hinahina* the flowers are red and bilaterally symmetrical



PLATE 50.—Three-Toothed Hinahina. (Original).

in regard to the position of the petals; in all others they are white, often marked with purple, and always star-shaped. They invariably mature their stamens and their pistils at different times, thereby preventing a flower from being fertilized with its own pollen.

The plant that at present goes under the name of *Geranium tridens* Hilleb., (Plate 50) is still common on the northern and eastern slopes of Haleakala where cattle roam. It grows in the open among the rocks and hard soil above 5,000 feet and, therefore, may be seen along the trails leading to the Rest House. It is a small, stiff shrub, rarely attaining a height of three feet. The flowers are white, and more or less purplish-veined especially toward their centers. The leaves usually stand erect and are about as silvery with hair as are those of the famous silversword (p. 306) occasionally found in the same region. This is probably a special adaptation to withstand the rays of the sun which are more active at higher than at lower elevations because of the lesser thickness of atmosphere which they must penetrate. Leaves that stand upright expose their surface far less directly to the sun than do those that lie flat. And leaves that are covered with white hair not only repel many of the sun's rays like a mirror from their surface but hinder the excessive evaporation of moisture through the epidermis.

Two plants that are similar to *G. tridens* are called *G. multiflorum* A. Gray and *G. ovatifolium* A. Gray, the latter being the arborescent type mentioned above. Both grow in the Koolau Gap of Haleakala where they are exposed to the fog and rain that usually begin to sweep into the crater in the late morning. At that time, however, neither fog nor rain can penetrate far beyond the Gap into the crater before being evaporated by the drier air with which it there mingles. As the day progresses, the clouds roll farther and farther into the crater until in the late afternoon it often drenches the surface of the cinder cones where the silverswords thrive, or may even fill the entire bowl of Haleakala. In this way, the *hinahina* are enveloped and drenched by clouds for most of the day, while the silverswords, growing barely three miles away, are exposed to intense sunlight and dryness.

G. arborescens A. Gray (Plate 51), the kind with red flowers, is the strangest plant of the entire group. It is a shrub growing in a few ravines on the outer slopes of the crater above Ulupalakua and Olinda. This plant grows within the cattle ranges and therefore



PLATE 51.—Red-Flowered Hinahina. (Original).

may become exterminated any day. *G. cuneatum* Hook., a kind resembling the one figured on Plate 50, grows within the Kilauea Section of the Park but only near the summit of Mauna Loa where few visitors will ever find it.

All these native relatives of the geranium are highly ornamental and extremely interesting. Unless considerable care is taken to protect the rarer kinds by fencing them from cattle and pigs, they will be exterminated within a comparatively few years. Those requiring particular care at this time are *G. arboreum* and the plants growing in Koolau Gap, the most interesting botanical region in the crater. This is, unfortunately, just beyond the boundary of the National Park.

PELEA, THE ALANI, AND THE MOKIHANA

The group of plants named *Pelea* by the American botanist Asa Gray in honor of Pélé, goddess of Hawaiian volcanoes, is almost entirely limited to these islands, only three or four kinds being known from other regions, all in the Pacific. About thirty kinds have been described from Hawaii and several yet remain to be described from the writer's herbarium. It is probable, also, that over a dozen undiscovered *Pelea* still grow in our forests. All these plants belong to the *Rutaceae* or Orange Family.

The *Pelea*, known chiefly as *alani* by the Hawaiians, are trees of usually small size. They bear rather inconspicuous, yellowish flowers, some of which finally mature into capsules. In certain kinds, these are round in shape, but in others they are square or even roughly cross-shaped. Before these capsules dry and split along their four grooves to liberate their black, shiny seeds, one may often see many small dots clearly marked upon their surface. These are reservoirs containing volatile and usually fragrant oil. The leaves of the *alani* are more or less leathery, have smooth margins, and usually emit a fragrant odor when bruised. This is caused by the breaking of still smaller oil reservoirs that are scattered by the thousands just below the surface. The leaves and rind of the orange contain ethereal oils in a similar manner and produce a somewhat similar odor when crushed. Therefore, when the orange was introduced into these islands by Vancouver, the Hawaiians named the tree *alani* because it reminded them of certain *Pelea*.

A typical plant, figured on Plate 52, may be seen in the interesting Kipuka Puauhu near Kilauea. It is known as *Pelea*



PLATE 52.—Pelea or Alani. (Original).

Zahlbruckneri Rock. As in all plants of this group, it bears flowers that are on the point of becoming unisexual, a condition paralleling that of the *Broussaisia* (p. 166). The ancestors of the *Pelea*, no doubt, produced flowers possessing normal stamens and pistils. Today, however, about half of the flowers on a tree bear functioning pistils and abortive stamens, as the figure of the dissected flower shows, while most of the others bear functioning stamens and degenerated pistils. The remaining type of flower in which both stamens and pistils can function is a persistent ancestral type.

Though the particular *Pelea* called *P. anisata* Mann, because of its anise-like fragrance, is not found within the area covered by this floral guide, it is mentioned because of its high esteem in the eyes of the Hawaiians, who know it as *mokihana*. The plant is peculiar to the Island of Kauai where it grows in the rain forest. Its capsules, the most fragrant part of the plant, were strung into *lei*, or garlands, which remain fragrant almost indefinitely. These can not be worn by some people without producing a rash where they touch the skin most often. In the "Song of the *Lei* of the Hawaiian Islands," the *mokihana* is emblematic of Kauai.

CANDLENUT TREE OR KUKUI

The candlenut tree (Plate 53), known throughout the Hawaiian Islands by the native name of *kukui*, is a member of the *Euphorbiaceae* or Spurge Family. Its scientific name is *Alcurites moluccana* (L.) Willd. It is a plant of wide geographic distribution, growing in the tropics and subtropics of the Old World, in the West Indies, in Brazil and elsewhere. It is native to these islands, where it grows abundantly on the lower slopes of mountains and in the lowlands, particularly in ravines.

Along the roadside from Hilo toward Kilauea one can easily recognize the *kukui*. The light-colored, greenish leaves, covered, especially on the under side, with a silver-gray powder, makes it very conspicuous in the forest (Fig. 2). The tree, in the most favorable places for growth, frequently exceeds a height of ninety feet, although usually it is but half as high. The trunk is occasionally smooth, straight, and unbranched to a height of forty or more feet. The small flowers are borne in clusters at the ends of branches. Two kinds exist: the staminate, or "male," bear about eighteen stamens each and no ovary, while the pistillate, or



PLATE 53.—Candlenut Tree or Kukui. (Original).

"female," bear a two-celled ovary and no stamens. The petals of both staminate and pistillate flowers are pale cream-color.

The pistillate flowers finally develop into more or less spherical fruits about one and a half inches in diameter, each containing one or, rarely, two seeds. The outer part of the fruit consists of a hard, green covering about one-fourth of an inch in thickness. Within this is found a thin crust-like shell most easily visible after the fruit has partly decayed. This surrounds the seed. The latter, in turn, consists of a thick, wrinkled, woody seed-coat which protects a large quantity of oily tissue called endosperm. This is not part of the embryo which later develops into the seedling, but food stored up for it by the parent plant. The embryo, composed largely of a minute stem and two flat leaves, termed cotyledons, lies between the two halves of endosperm. When conditions are favorable for germination, the cotyledons exude a slippery secretion which actually softens and liquefies the endosperm. This is then gradually absorbed by the seedling, thus furnished with nourishment until it has had the opportunity to become established in the soil and to begin the manufacture of food for its own life processes.

The *kukui* was of great value to the early Hawaiians, being used for light, navigation, fishing, tanning, dyeing, food, medicine, catching of birds, ornamentation and even for the detection of criminals.

The use of the *kukui* for illumination by the various Polynesians has always impressed strangers, as the common English name, candlenut tree, testifies. The Hawaiians, alone, had four ways of using the *kukui* for light. The simplest way was probably by means of the *lama*. This was essentially a torch consisting of a piece of bamboo whose hollow had been stuffed with roasted *kukui* kernels or some other combustible material.

The second type of lighting was produced by the *kalikukui*. This was made of *kukui* nuts first roasted in the shell and then hulled, or merely shelled and allowed to dry in the sun. These kernels were then strung on a short piece of midrib of a coconut leaflet, or on a long sliver of bamboo. Such a torch, lighted and rested against a stone, would illuminate the huts during the evenings. It was usually tended by one of the children in the family, who, as the uppermost kernel was beginning to burn away, would invert the torch so that the remaining flame should ignite the adjoining kernel. When this had been accomplished,

the entire torch was righted again and the remains of the old, uppermost kernel knocked off with a short piece of wood. Each nut burned two to three minutes.

An *aulama*, on the contrary, consisted of half a dozen or more *kalikukui* wound up parallel together with dry banana leaves into a cylinder about three to six inches in diameter and from two to four feet long. Such a torch produced a bright light convenient for a nocturnal dance or a religious service in the *heiau*. Besides the light, such a torch gave off abundant smoke and an odor akin to roasting peanuts, which made its use within huts objectionable.

The highest type of Hawaiian illumination was produced by the stone lamp, called *pohokano* or *pohokukui*, of which various examples are pictured in Fig. 36. These resembled the early lamps



(From collections of Warinner and Degener.)
FIGURE 36.—Stone lamps or *pohokukui*.

of the Caucasian. The Hawaiian lamps were filled with *kukui* nut oil or more rarely with the oil of the coconut (p. 68) or the true *kamani* (*Calophyllum inophyllum* L.), or with some animal fat. The *kukui* oil was gained in one of two ways: entire, single torches were lighted at one time for illumination while the heat would cause much of the oil to run out of the kernels and drop into a container placed below; or the oil would be expressed from the kernels in a stone mortar. For light a strip of twisted *kapa*, placed hanging over the rim of the filled lamp, was ignited as a

wick. If more light were needed, additional wicks were simply added to the rim of the lamp.

The trunk of the *kukui* tree, though composed of extremely soft and easily decaying wood, was in very rare cases hollowed out and fashioned into canoes. The wooden floats, *ikoi* or *lana*, for fish nets were also made of *kukui* if the superior wood of the *hau* (p. 215) was not available.

The kernels of the *kukui* nut, or the meat of the coconut, were chewed by the Hawaiian fisherman and then blown out of the mouth over the sea. Sufficient oil from these nuts would thus be spread over the water to quiet its ripples. The oil was probably not first derived from the kernels and then spat over the water as has been intimated by others.

For fish nets, the *olona* (*Touchardia latifolia* Gaud.) was used in preference to the related *mamake* (p. 130). Its fiber was stronger and more resistant in water. To tan such a net in order to strengthen it and hinder decay, as well as to stain it to make it less conspicuous to the fish, it was treated with an infusion of *kukui* bark. The inner bark was taken from an old tree, pounded and then put into a trough with water. After stirring, the bark was strained out. The new nets were dipped into this liquid and allowed to dry, and thereafter dipped and dried a second time. This preserved them as well as stained them a reddish color. If a net is used frequently, it should be dipped at least once every month or six weeks in such a bark infusion as the effect of the treatment seems to become lost by long immersion in the ocean. Nets thus treated have been known to be serviceable for fifteen years.

The *kukui* furnished several dyes. The bark of the root was pounded to form a stain which was mixed with the finely chewed kernels of the nuts. This oily dye was then used to stain *kapa* (p. 137) a copper color. At times, a dye was made from the male inflorescence of the breadfruit (p. 124) and the bark of the *kukui*. Another dye was made from the broken shell of the *kukui* fruit and of the bark of the tree trunk. The bark of the root, on the other hand, mixed with charcoal, was used in coloring canoes black. Another black dye was prepared from the acrid juice derived from the hard, green covering of the nut. A far superior black, however, was produced from the soot that collected on smooth, clean pebbles under which *kukui* nuts had been

burned. This was even used for tattooing. A second dye for tattooing was prepared from the fleshy covering of the green fruit.

From wounds made in the bark of the *kukui*, a dark, resinous gum, called *pilali* by the Hawaiians, exuded. After dissolving this in water for a day or two, the liquid was used as an adhesive or painted on *kapa* with a brush, called *huluana'i*, made from part of a coconut husk or *hala* (p. 47) fruit. This protected the dye and made the cloth more durable and waterproof. *Pilali* was also eaten.

The oily flesh of the *kukui* nuts is somewhat poisonous to eat in the raw state, as one might expect from the fruit of a member of the *Euphorbiaceae*. After eating two or more nuts, one is likely to become ill. This poisonous quality is largely changed by roasting. In that state the kernels are prepared by the Hawaiians to make various edible dishes called *inimona*. They may be merely pounded in a stone mortar with sea salt to be eaten as a relish. Or they may be mashed, mixed with salt and the fruits of the red pepper (*Capsicum frutescens* L.), or sometimes with the dried ink bag, *alaala-hea*, of the squid. It is advisable for the visitor to partake sparingly of *inimona* until he has observed how this dish agrees with him.

The plant also furnished the Hawaiians with various medicines. *Waiki*, a remedy for a skin disease, consisted of the core of an unripe calabash gourd and the sap of the *kukui* tree. A purge, *akukapihe* or *kukapihe*, was made from the bark of a native, small-leaved euphorbia called *koko* and the sap, called *waikea*, of the green *kukui* fruit. A medicinal drink, called *piiku*, was derived from the sap of the tree. For the infants' disease called *ea* (p. 20), the *kukui* was used in several ways. The fresh juice seeping from the broken stem of the young *kukui* fruit was put on the finger and allowed to become partly dry. This was then rubbed over the infected area in the child's mouth. Or the patient ate the flowers of the *kukui* pounded together with boiled sweet potatoes. Yet another remedy for *ea* was made by allowing the *kukui* nut to burn to charcoal and then rubbing this on the infected area.

The hard shell of the ripe *kukui*, after its ridges had been rubbed away with a stone, was buried in a marsh to season and blacken. Then it was carefully polished with the large stipules of the breadfruit tree (p. 129) and oiled. These nuts when strung into a necklace remarkably resemble one made of jet. The

feet of birds caught with birdlime (p. 129) were washed with the oil of the *kukui* nut. Then the birds were liberated.

The *kukui* even aided in the detection of crime in the early days. If an object had been stolen, the priests, or *kahuna*, were often asked to discover the offender. The complainant usually paid the *kahuna* a pig before the following ceremony was performed: Two sticks of green wood were rubbed together until the friction produced a smoldering powder which, when blown upon, would ignite some dried grass. With this a pile of wood was kindled. Three *kukui* nuts were then broken, and one of the kernels thrown into the fire. While this was burning, a prayer was uttered, accompanied with the anathema that the thief should be killed. If the thief appeared and made restitution, which generally followed, he was merely punished with a heavy fine. If the culprit did not make himself known, the ceremony was repeated with the remaining nuts. A proclamation was then made throughout the island by the king that a theft had been committed and the guilty prayed to death. Nothing more was done, as the thief's death was considered inevitable. So firm was their belief in the power of these prayers to arouse the avenging deity, that the guilty one usually pined away and actually died of fright. This is not surprising when one recalls with what fear the European regarded papal interdicts not many centuries ago.

With the coming of the white man, the importance of the *kukui* in the economy of the Hawaiian gradually declined. *Kukui* lamps persisted in use in the country districts until about 1865. The nuts, rich in their oil, which was a good substitute for linseed oil, were formerly gathered in large quantities and sold to the Russians for use in their settlements on the northwest coast of America. At one time as much as 10,000 gallons of *kukui* oil was exported from these islands in a single year. As the pay of labor steadily increased, however, the cost of picking up the fallen nuts left no profit from their sale, and the industry ended. Today, the polished shells of the nuts may be seen occasionally in curio shops in the form of *lei*, watchfobs, rings and necktie clasps.

DODONAEA OR AALII

Several kinds of *dodonaea*, known as *aalii* in Hawaiian, are found in these islands. All, except possibly one kind, are endemic. Some botanists consider that these plants and about fifty close relatives growing elsewhere, constitute a distinct family of their

own, the *Dodonacaceae* or Dodonaea Family. Others place them in the *Sapindaceae* or Soapberry Family.

Dodonaea spathulata Smith, sometimes known as *aalii kumakani*, is a shrub growing abundantly in the vicinity of Kilauea and on the slopes of Mauna Loa, Mauna Kea and Hualalai of the Island of Hawaii. These plants are one to rarely six feet high. They are either "male" or staminate, bearing flowers with numerous pollen-filled stamens and no pistils; or they are "female" or pistillate, bearing flowers having pistils but lacking stamens. A large staminate twig fills the greater part of Plate 54, and a flower cluster from a typical pistillate plant is shown in the upper right-hand corner. Below are two different diagrammatic views of a capsular fruit that has developed from a pollinated pistillate flower. These capsules are always borne in open clusters and are either yellowish or bright red, imparting a very ornamental effect to the shrub. Most of the capsules have three wings, but some have two, and a very few have four wings. They are smooth, and are neither sticky nor inflated like those of other kinds of dodonaea.

Dodonaea eriocarpa Smith, the *aalii kumakua* of the Hawaiians, has several varieties. It is found on the Islands of Hawaii, Maui and Kauai. On the Island of Hawaii it may be seen to best advantage in the aa lava flows near the little village of Punaluu, about twenty miles southwest of the Kau entrance to the Kilauea Section of the Park. This plant differs from *D. spathulata* growing near Kilauea in having distinctly hairy leaves, and in having its capsules three- or four-winged, somewhat hairy, slightly inflated, and borne in compact, almost spherical clusters. The plants known as *D. eriocarpa* growing on the Island of Maui on the slopes of Haleakala and within the crater itself, are somewhat different.

The dodonaea were sacred to Laka and to Kapo, the goddesses of the *hula* (p. 53). Various parts of the plant were used by the old Hawaiians. Because of the extreme hardness and durability of the wood, the dodonaea when found of sufficient size were sometimes cut into timber for building houses, or fashioned into spears and other weapons.

The brilliant red capsules were also gathered, placed in a calabash with water and brought to a boil by dropping hot stones among them. The liquid, becoming as red as ink, was strained and then used for dyeing *kapa* (p. 137) and other articles.



PLATE 54.—*Dodonaea* or *Aalii* Kumakani. (Original).
 Branch of staminate, or "male," plant; twig of pistillate or "female" plant; 2 mature capsules.

SOAPBERRY TREE, AÉ OR MANELE

The soapberry tree (Plate 55), called *aé* or *manele* by the Hawaiians, is botanically known as *Sapindus saponaria* L. It is native in several slightly different forms to certain regions in tropical and subtropical America as well as in the Orient. It is also native to the Island of Hawaii but not to the other islands of this group. With the *aalii* (p. 199), it belongs to the *Sapindaceae* or Soapberry Family.

Some soapberry trees almost eighty feet high may be seen in the Kipuku Puaulu near Kilauea. They have compound leaves and clusters of small, yellowish flowers that secrete abundant nectar. These flowers are apparently evolving into completely unisexual structures as are those of the *Broussaisia* (p. 166) and the *Pelca* (p. 193) previously described. Although all the flowers bear stamens, only those lacking pistils have stamens that ever produce good pollen (Plate 55, at base on left). These are consequently true staminate, or "male," flowers. The other type of flower (Plate 55, at top), which may be termed the pistillate, or "female," flower, is peculiar. It not only bears worthless stamens but usually two of the three seed-producing organs, called carpels, that constitute the compound pistil, have degenerated also. Consequently when they have matured into fruit, the result of this abortion is greatly magnified. Instead of consisting of three equal spheres mutually united, the fruit consists, as the bottom of the plate shows, of one that is almost an inch in diameter and two that are about one-fourth as large. Of these three, only the large sphere contains the seed. The logical explanation for the occurrence of these two aborted structures is that the ancestors of the soapberry tree originally bore fruit containing three viable seeds.

When the fruit of the soapberry tree dries, the flesh shrinks away from the seed to form a cavity filled with air. In this state every seed can float. When removed from the fruit, however, about half of the seeds sink in fresh water and one fourth in sea water. Whether the plant owes its wide distribution to the floating ability of all of its fruits and at least half of its seeds is not definitely known.

No particular Hawaiian use for this tree is known. The fleshy fruit is rich in the chemical, saponin, which has the property of making a lather. It therefore can be used as a substitute for soap. As saponin is somewhat poisonous, the fruit is unfit to eat. The



PLATE 55.—Soapberry Tree or Manele. (Original)
Pistillate flower; staminate flower; fruit showing peculiar development of carpels; seed.

black, spherical seed, which is about half an inch in diameter, has been used extensively in the manufacture of rosaries.

KAUILA

Two plants, both growing in arid regions, are known as *kaula* to the Hawaiians. The one is *Colubrina oppositifolia* Brongn., a tree peculiar to the Hawaiian Islands; the other is *Alphitonia zizyphoides* (Spreng.) A. Gray, a tree of wide distribution in Pacific regions. Both belong to the *Rhamnaceae*, or Buckthorn Family.

The *colubrina* is very rare in Hawaii National Park but may be seen in considerable numbers near Puuwaawaa on the Island of Hawaii. It is a smooth tree bearing shiny leaves in opposite arrangement. These are very characteristic in possessing conspicuous glands on their under side where the veins branch off from the midrib. The flowers are borne in clusters in their axils. Each flower is small, yellowish-green, and star-shaped because of its five, spreading sepals. Between these are borne both petals and stamens. As the petals are concave and contain the stamens, it is difficult to recognize both structures. Though the flowers are not conspicuous, they are dependent on insects for pollination. These are well repaid for their labor by abundant nectar which exudes from a flat, glandular disk located between stamens and pistils.

The fruit of the *colubrina* is a spherical, rather woody capsule bearing the remains of the calyx at the very base. It has three shallow, vertical grooves, along which the fruit finally splits open into three segments, each liberating a single, naked, dark gray seed from its inner side.

The *alphitonia* (Plate 56) may be seen in the vicinity of the Kipuka Nene south of the Crater of Kilauea. It closely resembles the *colubrina* but may be readily distinguished from it by a few well-marked features. The leaves are arranged alternately on the stem, and their under surface is hairy and free of glands. The fruit, instead of bearing the remains of the calyx at its base as in the *colubrina*, bears it as a circular ridge a considerable distance above. It also lacks the three longitudinal grooves found in the other plant and therefore does not split into three definite parts at maturity. Instead, the woody capsule gradually breaks away in irregular fragments from the seeds. These are invested with a



PLATE 56.—*Alphitonia* or *Kauila*. (Original)

peculiar, brown, brittle crust termed aril, and frequently remain attached to the fruit stalk for a long time.

Both kinds of *kauila* have extremely heavy, hard wood which was of great value to the Hawaiians and highly prized by them. Because of a phallic symbolism connected with the alphonsonia, however, the wood of this tree was not used for religious purposes. That of the colubrina was used in its place. But for non-religious purposes, the alphonsonia was commonly employed.



FIGURE 37.—Hawaiian chief, sitting before door of grass hut, with two youths bearing small *kahili*, or feather standards, in his honor; woman beating *kapa* cloth with *ie kuku* on the *kua kuku*; three spears, or *pololo*; a rack, or *haka*, to which calabashes, or *umcke*, are fastened by means of coconut fiber rope.

When priests met for the purpose of prayer and sacrifice to ward off evil, the *kahuna nui*, or high priest, held in his hand a piece of *kauila*, or colubrina, wood wrapped in dark *kapa* (p. 132) as a symbol of his authority.

The *kahili* (Fig. 37), a feathered standard of the Hawaiians

probably in vogue since the time of Hawaii Loa, was an emblem of rank carried on special occasions. It consisted of a pole or spear of *kauila* or of *koa* (p. 173) wood usually ten to twenty feet long. The upper third or less of the pole bore many branches made from the stiff midribs of coconut leaflets. The branches, of which there might be hundreds, were simple or forking and would radiate in all directions. To their ends were tied tufts of short, bright feathers to form a regular, plumed cylinder, or *hulumanu*, fifteen to thirty inches in diameter. After the occasion for the use of the *kahili* had passed, the *hulumanu* was taken apart and the feathers stored away in tight calabashes containing the leaves and stems of a certain pungent, insect-repelling *Gnaphalium*, called *enaena* by the Hawaiians.

The pole was the essential part of the *kahili*. To it much sentiment was attached. It was often elaborately ornamented by the chiefs as a pastime. The handle was made by stringing disks of tortoise-shell on its lower end, these often alternating with disks of bone. All were then carefully filed and polished until a smooth, variegated handle resulted. The bones were frequently derived from the shins of brave warriors who had been killed in battle by the owner of the *kahili* and thus signally honored by him. If, however, the enemy had been despised, his bones would not be inlaid in a *kahili* handle, *poi* bowl or sacred drum, but, possibly along with his teeth, in a spittoon or slop basin instead. Or his bones might be employed in the making of fishhooks, those from smooth-skinned and not hairy individuals being preferred because of the belief that the fish first preferred those made from the former individuals.* Or as an especial insult, the bones might be fashioned into arrowheads for use in the chiefly sport of shooting the native rat.

A dying chieftain, to prevent the desecration of his bones, would choose some trusted friend to conceal them after his death, with the remark that he did not wish his bones to be made into fishhooks or into arrowheads with which to shoot rats. This last was a sport much practiced by the chiefs and the only use to which the bow and arrow were put. When death was imminent, the chief's heir would leave the district so as not to be

* A certain commoner won such an enviable reputation as a fisherman that it was thought his success depended on the character of his bones. If this were true, it was argued, then he would be of more value to the king and chiefs in the form of fish hooks used by many, than alive as a single, active fisherman. The experiment was therefore tried to his detriment.

considered polluted by his father's death. Shortly after the chief's death, the corpse was wrapped in banana, taro or *loulou* palm leaves and placed in a shallow, temporary grave. Over this a fire was kept burning, amid the saying of prayers, for about ten days to hasten dissolution. Thereafter the body was disinterred and usually taken out to sea where the bones were carefully stripped of all flesh. They were then tied up in a bundle with coconut fiber, and covered with *kapa* and a red feather cloak. With the making of this bundle, the first part of the funeral ceremony was complete. A hog was offered as a sacrifice and the heir returned from his seclusion. Then followed the *huna kele*, or concealment of the bundle of bones, preferably in some inaccessible cave, or the bones were enshrined in the *heiau* as a god.

During such periods of national mourning, all clothing was cast aside by the populace, and all customs and restraints ignored. The people often knocked out their teeth and cut their hair in fantastic ways. This cutting was done with the *niho oke lauoho*, an instrument consisting of a shark's tooth tied to a stick. The hair was merely bent over the tooth and then cut with a sawing motion. If this method was too painful, the hair was carefully singed off.

The *kauila* was one of the trees whose wood was preferred in the building of the ancient Hawaiian grass hut (p. 268). It was also used in the manufacture of the *ie kuku*, or *kapa* beater (p. 133, Fig. 31), because of its great hardness and durability. For the same reason it was made into weapons such as the spear, or *pololo* (Fig. 33), twelve to twenty feet long; the javelin, or *ihe*, about one-third as long; and the dagger, or *pahi kauwa*. When enough of this precious wood was available, it was often fashioned into the *oo*, an agricultural implement for digging. This was little more than a stick flattened and sharpened at one end. Thus the *kauila*, together with stone, took the place of metals in the life of the early Hawaiians until after the discovery of the Islands by Captain Cook. It is true, however, that they knew of metals before that date, as Cook himself attests. This knowledge must have been derived from the metal parts of some wrecked Spanish vessels of which several accounts are incorporated in ancient, Hawaiian *mele*, or epics.

Rounded and polished rods of *kauila* were used as hairpins by the Hawaiian women in the early days. Because of its weight,

which causes it to sink slowly in water, the fishermen employed the *kauila* in a peculiar method of trolling. They fashioned a club, called *laau melomelo*, a foot or two in length, having a swelling at the thinner end. Then the juice of the meat of the coconut, sugar cane pith already chewed to rid it of its sap, and various other ingredients were burned together and the club rolled around over the smoke of the mixture. Thereafter it was ready for use in trolling. A line was tied to the smaller end and the club dragged in the water from a canoe to attract fish that smelled the bait-impregnated wood. As the odor became gradually dissipated by continual submersion, this smoke treatment was repeated about once a month.

HIBISCADELPHUS AND RELATED PLANTS

The *Malvaceae* or Mallow Family is represented in these islands by the groups botanically called *Sida*, *Abutilon*, *Thespesia*, *Pariti*, *Hibiscus*, *Gossypium*, *Kokia*, *Hibiscadelphus*, *Malva*, *Malvastrum* and probably a few others. All but the two last listed are represented by one or more native kinds of plant.

The plants comprising *Sida* are generally called *ilima* by the Hawaiians. They are woody herbs or small shrubs usually growing in very arid districts. Their small, yellow flowers were formerly commonly strung into garlands, or *lei*, reserved for chiefs. These plants do not grow in any number in the National Park excepting near sea level where the climate is hot and dry.

The *milo* of the Hawaiians, *Thespesia populnea* (L.) Soland., from whose trunk beautiful bowls were formerly made, is not found within the Park but near the ocean in many other districts. The *hau*, *Pariti tiliaceum* (L.) Britton, especially mentioned on page 213 because of its great value to the early Hawaiians, is found usually in similar places.

The plants belonging to the botanical group *Hibiscus* are known by that name to the layman. Many kinds with yellow, white, pink or red flowers are native to these islands. Of these the pink-flowered kind, called *Hibiscus Youngianus* Gaud., may be seen growing along the roadside between Hilo and Kilauea. Those that are planted in so great profusion in gardens, however, are horticultural forms derived from the common Chinese hibiscus, *Hibiscus rosa-sinensis* L., by artificial breeding and selection.

Gossypium is the scientific name of the group of plants we

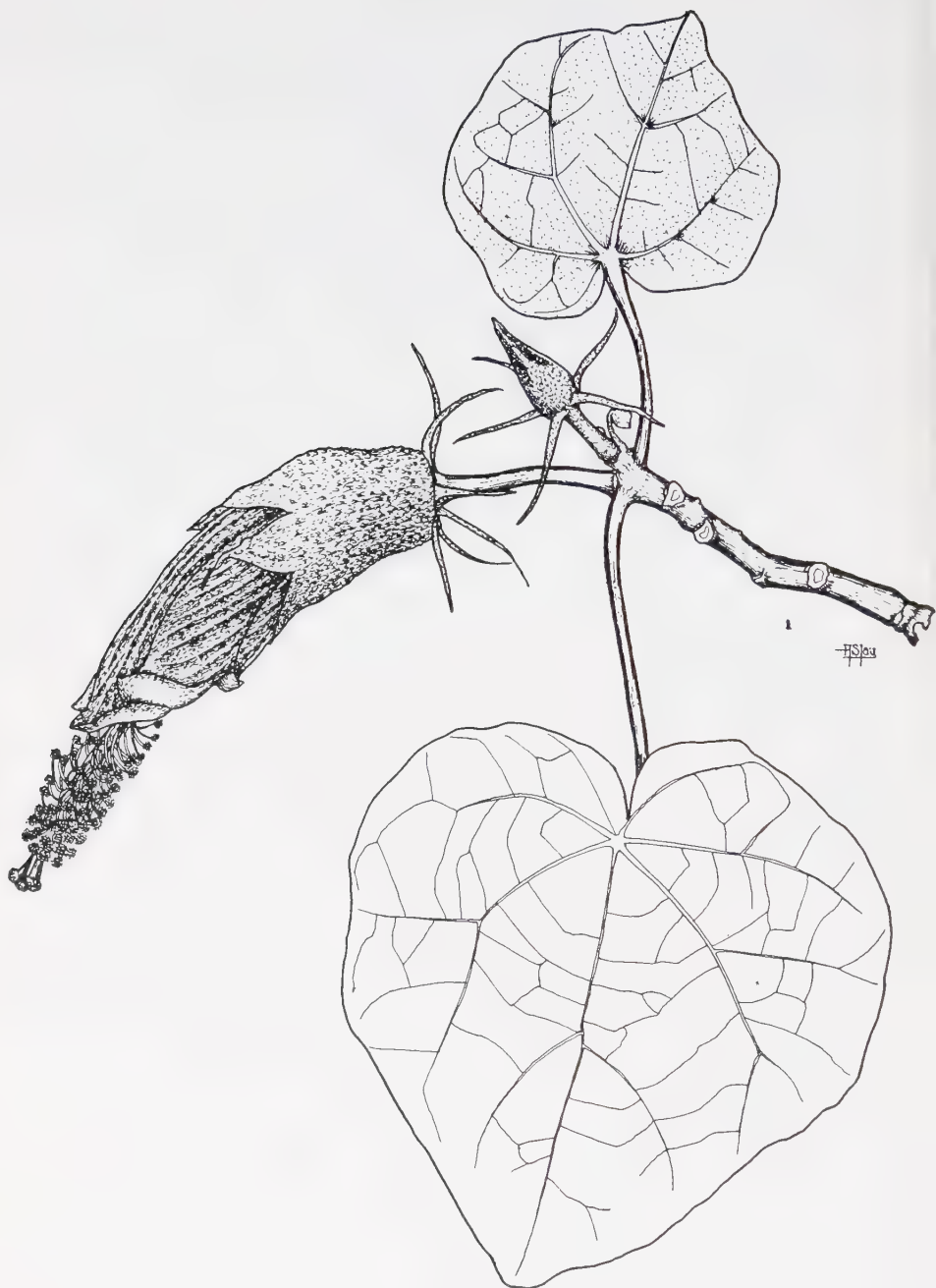
PLATE 57.—*Kokia*. (Original).

know as cotton. A beautiful kind, *Gossypium tomentosum* Nutt., with gray, velvety leaves and sulphur-yellow flowers is native to these islands. It grows in dry regions chiefly near the shore.

Kokia is a remarkable group found only in the Hawaiian Islands. It exhibits certain characteristics that are similar to those of the hibiscus while other characteristics resemble those of the cotton. Only three kinds are known to have existed in the entire world. One, growing on the eastern end of Oahu, has long become extinct due to the ravages of cattle. Another, called *Kokia drynarioides* (Seem.) Lewt., consisted of a single tree growing on West Molokai in 1913. This is now dead. But one tree grown from a seed produced by this last wild plant is at present growing in a Molokai garden. Of the third *Kokia* (Plate 57), called *K. Rockii* Lewt., about two hundred trees were living in 1930 in a very localized area amid the dry lava flows between Huehue and Puu-waawaa, on the Island of Hawaii. This plant has such beautiful, large, brick-red flowers that it is well worthy of cultivation. Unfortunately, the plants are not increasing in numbers, though producing abundant seed, because these are eaten by rats soon after falling to the ground.

Hibiscadelphus is another strange group of plants limited to Hawaii and Maui only. Wilder's hibiscadelphus consisted of a single dying tree in 1912 on the southern slope of Haleakala, Maui. The plant is now apparently extinct. The Hualalai hibiscadelphus grows on the mountain of that name on the Island of Hawaii. In 1923 only about a dozen plants were surviving. The third and only other kind of hibiscadelphus in the world was named after the late W. M. Giffard, *Hibiscadelphus Giffardianus* Rock. Only one dying tree has ever been found, and this still survives at the time of writing*, near the Kipuka Puaula within a few miles of Kilauea Crater. Fortunately, seeds of this strange tree were planted by Mr. Giffard and now four thriving trees are growing at his former country home. Though flowering abundantly, these five plants produce no seed unless artificially pollinated. It would be a great loss to science if this strange member of the Mallow Family were neglected and should become extinct. It bears magenta-colored flowers that resemble those of the hibiscus but, as the accompanying drawing shows (Plate 58), never fully expand.

* This tree finally succumbed in the summer of 1930

PLATE 58.—*Hibiscadelphus*. (Original).

HAU

The *hau*, preferably known botanically as *Pariti tiliaceum* (L.) Britton, is a member of the *Malvaceae*, or Mallow Family. It appears to be native to most tropical countries, growing typically along the strand though also far from the influence of the ocean. In the Hawaiian Islands it thrives from the shore to an elevation of about 2,000 feet on all but the drier regions. It is not found within the confines of the Park but may be observed by every visitor along the roadside upon driving to or from the boundaries.

The *hau* is usually a small tree producing numerous, long, spreading branches which readily strike root upon touching the ground. The plant with its matured seedlings therefore usually produces a dark, almost impenetrable tangle. The leaves are broadly heart-shaped, smooth above and velvety below. The large flowers are borne singly or a few together in the axils of the upper leaves and at the ends of the branches. They closely resemble those of the hibiscus excepting that the modified leaves, called bracts, surrounding each flower, are not free but are grown together almost to their tips, as the illustration shows (Plate 59). When the petals of the flower expand, they are sulphur-yellow in color, with or without a brownish center. With the advance of day, they gradually change to a reddish tinge, and the following day drop to the ground a rich brown. After several months the capsules, that have developed from the part of the flower remaining on the plant, split open to shed their seed.

The *hau*, because of its usefulness, was held in such high regard by the Hawaiians in former days that it was a grave offence for a commoner to cut any of its branches without first gaining permission from a chief to do so. The extremely tough, pliable inner bark, the *ilihau*, was stripped from the trees and then used for rope, or it was first dried and then wetted before using. Without wetting, it was too stiff for tying. Several such strands of rope plaited together formed a hawser with which logs of *koa* (p. 173), roughly hewn into the shape of canoes (p. 175), were dragged from the mountains to the shore. There the work of finishing the canoes was continued. Even as late as 1824 the natives on the Island of Kauai collected an enormous quantity of *hau* bark with which they made strong hawsers several thousand yards long. Three cables, each made from twelve of these hawsers, were then fastened to the wreck of the royal "Cleopatra's



PLATE 59.—Hau. (Original).

Barge" in a vain attempt to drag it ashore. The bark of the *hau* not only served as binding material but was occasionally beaten into a good quality of native cloth, or *kapa* (p. 132). A demulcent, *hauoki*, was also prepared from the bark and given as a medicine in childbirth.



FIGURE 38.—Fishermen repairing *olona* fish nets to which *ikoi*, or floats, are attached.

Ikoi (Fig. 38), or fish net floats, were made from the *hau* or from the *wilowili* (*Erythrina monosperma* Gaud.). The branches, usually two inches in diameter, were dried and cut crosswise into pieces at least three inches long. A hole was then easily made through them by the removal of the soft, central pith. The floats were now tied to the nets, by passing a cord through the pith cavity, at intervals of one or more feet.

In making fire, the Hawaiians were obliged to resort to fric-

tion. A pointed stick, the *aulima*, of some hard wood such as that of the *olomea* (*Perrottetia sandwicensis* A. Gray) which is found in the Kilauea Section of the Park, was rapidly rubbed in the groove of a block, termed *annaki*, of soft *hau* wood. The heat thus developed ignited the little heap of powder that had accumulated from the rubbing. The smoldering spark was then usually transferred to a handful of dry grass and this was moved to and fro in the air until it burst into flames.

The discovery of this method of making fire is legendary. Maui and Hina had four sons, Maui-mua, Maui-hope, Maui-kiikii and Maui-o-ka-lana. One morning at sunrise the four brothers launched their canoe from the beach near their home below Kaupo Gap, at the base of Haleakala, and proceeded to the fishing grounds. They were just beginning to fish when Maui-o-ka-lana saw a fire on the beach they had just left. They turned their canoe toward shore and hastened to investigate. Upon landing, Maui-mua ran toward the spot where the fire had been burning. The curly-tailed *alae* or mud hens (*Fulica alai* Peale), who had built the fire to roast some bananas they had stolen from the brothers, scratched out the flames and flew away. Maui-mua returned to his brothers and told them what he had seen. They decided not to go fishing again but to wait for the next appearance of the fire. They waited so many days in vain that they finally resolved to go fishing again. No sooner had they left for the fishing grounds when the fire appeared; as soon as they returned, it was extinguished. This happened repeatedly, the *alae* always knowing when the brothers had gone fishing. They also could tell, by counting the number of men in the canoe, whenever one of the brothers remained behind to discover the method of making fire, and they consequently refrained from making it. The four brothers finally outwitted the *alae* by dressing up a calabash in *kapa* and setting it in Maui-mua's place in the canoe. Maui-mua then secreted himself on shore while the three brothers set out for the fishing grounds as usual. The unsuspecting *alae*, believing they had the shore to themselves, built their fire. Maui-mua crept close to the birds and then suddenly ran forth and seized one, threatening to kill it if the secret of making fire were not disclosed. The *alae* attempted to lead him astray by telling him to rub different substances, none of which could produce fire. Maui-mua, after trying these without success, finally forced

the bird to part with her knowledge. Then in revenge for the *alae*'s conduct in inducing him to rub so many things in vain, Maui-mua rubbed the top of the bird's head till it was red with blood. The mark remains there to this day as evidence, it is said, of Maui-mua's exploit.

In early times certain kinds of fish were subject at definite seasons, often wisely coinciding with spawning time, to the *kapu* of Kuula, the fish god, who was thought to regulate their abundance. In addition to these religious restrictions, fishing along the shore and in shallow waters, both as to certain kinds of fish and to certain periods, was subject to the *kapu* set up by the landlord or by the king. The placing of *hau* branches along the shore proclaimed to all that the adjoining shallows were under such a *kapu*. The fishermen strictly respected this injunction, as death was usually the penalty for its violation. During the time such fishing in shallow water was forbidden, the people resorted to the deep sea for food. With the removal of the *hau* branches, the *kapu* was lifted and everyone could fish as before. In certain cases after such a season, the first fish of any kind caught was dedicated to Kuula. With the god's right to that particular kind of fish recognized, the people were free from further obligations regarding it. This custom was religiously observed by all fishermen throughout the islands of the Hawaiian group.

Because they are tough and light, and often grow in a convenient curve, *hau* branches were particularly suitable for adz handles. At one end a heel was usually cut to which the tang, or base, of the blade was attached by cords of *olona* (*Touchardia latifolia* Gaud.) or coconut fiber (p. 75). Between the wood and blade, a piece of *kapa* (p. 132), the dry leaf of the *hala* (p. 43) or of the banana were inserted. These blades in early times were made from a compact, grayish lava exposed only in a few localities, one of the best known being Keanakakoi Crater. The name of this crater, probably spelled originally *ke-hana-kakoi* and meaning "the adz-making place,"* was derived from the fact that the Hawaiians there found lava of a kind suitable for making their *koi*, or adzes. This ancient quarry was obliterated by a lava flow that most likely occurred in 1879.

* The meaning of the name of this crater has been given as "adz cave," *ana* meaning "cave" in Hawaiian. Since other *koi* quarries are likewise called *keanakakoi* it seems more likely to the writer that *ana* is merely a contraction for *hana*, meaning "make" or "work."

The wood of the *hau* was also made into outriggers, or *ama*, and into struts attaching them to the canoes (Fig. 35). That of the *wiliwili* was really better adapted for the purpose because of its greater lightness. In more recent years, however, it has lost favor because of the belief that sharks preferred to follow this particular wood. Whether this belief is based on some peculiar quality of the tree or is merely imaginary is not definitely known.

In the pastimes of the Hawaiians the *hau* also had its part. The natives often engaged in a game involving the use of long spears made of *hau* timber. These spears, hurled by strong men, went whizzing through the air at times for a distance of 1,000 feet. *Oahi*, the fireworks of the Hawaiians, was by far the most spectacular of all their amusements. This took place on the northern coast of Kauai where the cliffs drop perpendicularly almost 2,000 feet into the ocean. On these heights the performers stationed themselves with oiled, dried sticks of *hau* or some other light wood. At night each performer lit one of these inflammable sticks and cast it into the air to the delight of the spectators gathered in canoes hundreds of feet below. The blazing wood was buoyed up by the strong trade wind and able to drop only very slowly into the ocean. As fast as these sticks were lighted the performers cast them into space until, to the spectator below, the sky appeared to be ablaze with scores of comets and shooting stars rising and falling, darting seaward or receding toward the cliffs, crossing and recrossing each other in the most fantastic way. This weird spectacle, sometimes supplemented with glowing *kukui* (p. 193) nuts that quickly reached their goal, continued long into the night. One by one the oiled sticks were consumed and the blazing firebrands flickered and disappeared, or the winds gradually subsided and they glided slowly and gracefully into the ocean where eager hands were outstretched to receive them. With these burning sticks the agile youths branded their arms as proof of having witnessed the *oahi*.

It was customary for those ascending these heights to carry bundles of green sticks and *kukui* nuts to the top and to scatter them about to dry. In this way, the proper fuel would be available for the succeeding performers to cast over the precipice.

When armies went to battle, a *kahuna* bearing a branch of the *hau* preceded each contending side. These branches were set upright in the ground by the bearer as a favorable omen. Both

armies chivalrously respected the *hau* emblem of the enemy and the *kahuna* guarding it. When one side finally realized defeat, its *hau* branch was allowed to fall.

PASSION-FLOWERS

Not a single member of the *Passifloraceae* or Passion-Flower Family is native to the Hawaiian Islands, though more than a dozen kinds now grow here. Several of these have escaped from cultivation and now may be seen growing along the roadsides and in the forests not far from the boundaries of the National Park. All, except a few kinds, are native to tropical and subtropical America.

Almost all the passion-flowers are tendril-bearing vines. They are remarkable for their flowers which have a very complicated structure. The description of a typical one should be understood with little difficulty by following the lettered drawings in figure 39.

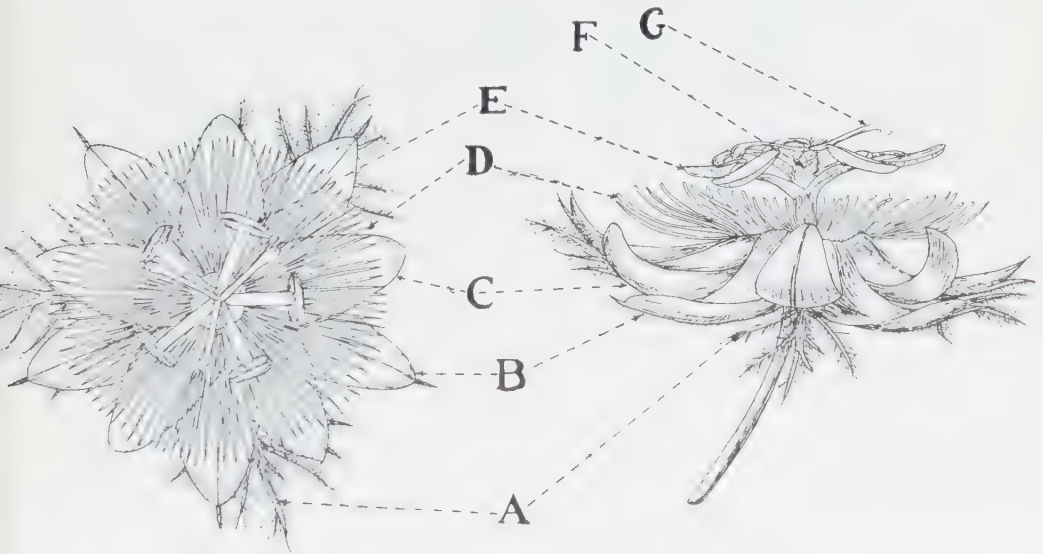


FIGURE 39.—Origin of the name of the passion-flower:

- A Leaf
 - B Sepal
 - C Petal
 - D Corona—either the halo or the crown of thorns
 - E Stamen—either the 5 wounds or the hammers
 - F Ovary
 - G Style—nails
- } 10 Apostles, Peter and Judas being absent

On the very outside of the flower are three green leaves (A) which, in the particular kind of passion-flower depicted, are deeply slit into segments bearing glandular hairs. Within are borne five sepals (B), which protect the more delicate parts of the flower from injury while yet in the bud. Alternating with these and above them are five colored petals (C). Within, is borne the receptacle, a remarkable outgrowth from a part of the flower. This outgrowth consists of tentacle-like appendages, often brightly colored, collectively named the corona (D). On a stalk arising, not from the corona, but from the inner base of the flower, are attached the remaining organs. First come five stamens (E) which bear at their ends the pollen-containing anthers. A small swelling above the attachment of the stamens is the ovary (F). This contains the ovules which later will develop into seeds. The ovary, in the meantime, matures into the fruit surrounding them. Finally, surmounting the ovary are three styles (G) bearing their stigmas at their ends.

When the Spaniards first saw the magnificent flowers of one of these plants hanging in rich festoons from the branches of the trees in the South American jungle, they regarded it as a token that the Indians should be converted to Christianity. Soon legends and superstitions connected with these plants became rampant because of the anthropocentric ideas of that time concerning the universe. For example, in 1610 Jacomo Bosio, author of an exhaustive treatise on the Cross of Calvary, was busily engaged on this work when an Augustinian friar named Emmanuel de Vuillegas, a Mexican by birth, arrived in Rome. He brought with him and showed to Bosio the drawing of a flower so stupendously marvelous that the latter hesitated to make any mention of it in his book. Later, however, some other drawings and descriptions of the plant were sent to him by inhabitants of New Spain, and certain Mexican Jesuits sojourning in Rome confirmed all the astonishing reports of this floral marvel. Bosio, therefore, conceived it his duty to present the *flos passionis*, or passion-flower, to the world. In his book he tells us that the flower represents not so directly the Cross of our Lord as the past mysteries of the Passion. Alluding to the bell-like shape assumed by the bud and the fading flower, he remarks: "And it may well be that in His infinite wisdom it pleased Him to create it thus shut up and protected as though to indicate that the wonderful mysteries of the



PLATE 60.—Foetid Passion-Flower. (Original).

Cross and of His Passion were to remain hidden from the heathen people of those countries until the time preordained by His Highest Majesty." To continue his article in brief, the five sepals (B) and the five petals (C) of the opened flower were supposed to represent the ten apostles present at the crucifixion of Christ, Peter and Judas being absent. The corona (D) was an emblem of the halo or of the crown of thorns. The stamens (E) were either the five wounds or the hammers used to drive the three nails which, in turn, were represented by the styles (G). The white color of the flower denoted purity while the blue markings represented heaven. The tendrils of the plant were supposed to represent the scourges, while the digitate leaves were the hands of the persecutors. Thus this plant stimulated the Spaniards in their zeal to spread their religious ideas throughout the New World with preaching as well as with fire and sword.

In the Islands two kinds of foetid or viscid passion-flower are very common in arid, waste places particularly near sea level. Both are hairy vines bearing their flowers within three comb-shaped leaves, called bracts, that are thickly beset with sticky, glandular hairs. The one kind, which is more common on the Island of Hawaii and is shown on Plate 60 and figure 39, has the lobes of its leaves somewhat rounded and its fruit yellow in color. The other, found more commonly on Oahu, has pointed lobes and bright red fruits. Whether the yellow-fruited plant is the true foetid passion-flower known botanically as *Passiflora foetida* L., and the red-fruited kind the variety, or *vice versa*, has not yet been definitely ascertained. The flesh of the fruits of both kinds, though small in quantity, is palatable when carefully eaten without touching the sticky, malodorous hairs. This flesh, called aril, is actually part of the seed, not part of the ovary wall.

The purple granadilla or *Passiflora edulis* Sims, a native of Brazil, was first grown in these islands at Līlikoi, Maui. As this passion-flower was unknown to the Hawaiians, they called it *līlikoi*, a name by which it is now known to everyone throughout the Hawaiian Islands. This vine has escaped from cultivation and may be found on the lower slopes of Haleakala on Maui, and especially above Waimea Canyon on the Island of Kāuāi. The leaves are deeply three-lobed and toothed along their margins. The flowers are white, marked with purple. Its fruit is two to three inches long and deep purple, and contains an edible, fragrant, orange pulp.



PLANT 61. ALA. (Original).

AKIA

More than a score of plants belonging to the group at present called *Wikstroemia* are native to the Hawaiian Islands. Many of these are yet imperfectly known and go under incorrect names in botanical literature. Most of them are found in dry districts as, for example, in the *aa* desert to the west of Kilauea. A few are found in moister localities, the one shown on Plate 61 coming from the forest northeast of Kilauea. Many of these plants are called *akia* by the Hawaiians. All belong to the *Thymeleaceae* or *Mezereum* Family.

The *akia* are shrubs or, rarely, small trees usually bearing many small branches. Their leaves are simple, have a smooth margin, and are frequently somewhat thick and leathery. The flowers, borne in terminal or axillary clusters, are yellowish and inconspicuous. They apparently are pollinated by nocturnal insects, being particularly fragrant at night. After several months these flowers develop into rather firm, orange-red fruits which are usually less than half an inch in diameter.

It is very difficult to break off a branch of the *akia* because of its extremely strong bark. This was employed by the natives for many useful purposes, being one of the best binding materials that the Hawaiian Islands afforded.

The *akia*, though harmless to the touch, is extremely poisonous if eaten. Its root and bark were used with certain parts of several other plants as an ingredient for a deadly drink that was designed for suicide, or for the execution of criminals by the order of a chief. The person presenting the poison in a cup called *apukohoho* addressed the doomed man with the expression, "*He wahi mea ola ia,*" meaning sarcastically, "This is to keep you alive."

The shrub contains an acrid, narcotic poison which, like that of a few other plants, was useful to the Hawaiians in catching fish by a method termed *hola*. This was fully described by J. F. G. Stokes, the able assistant to Director Brigham since the late '90s, and probably the foremost living student of Hawaiian Ethnology today. From Stokes we learn that the bark and leaves of the plant were taken and then thoroughly comminuted by pounding with a convenient stone on the rocks adjoining the stream or ocean where the fishing was to take place. The fishermen, to avoid the possibility of being bitten by eels if the fishing was to be in salt



PLATE 62.—*Tibouchina*. (Original).

water, placed double handfuls of the prepared plant in the fibrous sheath of the coconut leaf or in twisted bunches of grass. This poisonous material could thus be quickly thrust under the rocks or into crevices where the fish were thought to lurk, the sheath or grass being used for additional applications of bark and leaves later on. Such fishing was usually limited to tidal pools where the poison was not readily dissipated. At times, however, the natives even employed this method in the ocean by diving down and placing the material among the stones of the bottom. In a typical tidal pool within about ten minutes after the submergence of the poison, the fish would become so narcotized as to swim about aimlessly or to float on or near the surface of the water on their sides in a dying condition. In this state, they could be easily caught. Though frequently poisoned to death, they were used for food as exposure to this poison did not render their flesh noxious to man.

TIBOUCHINA

The tibouchina (Plate 62) is a very conspicuous shrub growing with great vigor along the roadside between the town of Glenwood and Kilauea Crater. Botanically it is *Tibouchina semidecandra* Cogn., a member of the *Melastomaceae* or Melastome Family. The plant is native to Brazil, from which country it was carried to Australia. About 1910 Mrs. C. F. Furneaux is said to have introduced it from there into the Hawaiian Islands because of its striking beauty.

The tibouchina is a tall shrub growing to a height of fifteen feet or more. Its hairy twigs are four-cornered and bear very characteristic leaves. These are ovate and have three to five prominent veins that arise from a common point at the end of the leaf-stalk or petiole. The leaves are densely covered on both sides with hair, that on the under side having a silvery sheen. The flowers are borne in open clusters at the ends of the branches and are red when about ready to open. When fully expanded they are very conspicuous with their violet to reddish-purple petals.

Though this shrub is very beautiful and attracts the attention of everyone that passes, it should be entirely eradicated from the Islands if it threatens to escape from cultivation. A very similar plant, the Malabar melastome (*Melastoma malabathricum* L.), introduced as an ornamental on Kauai, has become naturalized within the last few decades. It has already replaced nearly all

other vegetation in Kilohana Crater and is rapidly spreading from that locality into neighboring regions, smothering to death the more interesting native plants that stand in its way (Fig. 40). The crater is now a devastated thicket of worthless shrubs through which neither man nor beast can penetrate for any distance (Fig. 41). The introduction of the melastome and its ultimate spread



(Photo by Senda, Broadbent and Degener.)

FIGURE 40.—View of part of Kolohana Crater showing the extermination of all native plants excepting two or three *ohia lehua* trees by the shrubby weed known as the Malabar melastome.

over the lowlands of Kauai, and of probably all Islands unless these are carefully guarded, will be as great a misfortune as was the introduction of the gorse (p. 182), the lantana (p. 251), and the eupatorium (p. 300).

The beauty of the *tibouchina* should not blind us to the fact that it, likewise, might escape and expose the native flora, particularly that of the Kilauea Section of the Park, to a great handicap

in the struggle for existence. For the privilege of growing this beautiful plant in the garden, the flower-lover should conscientiously keep it from escaping into the open.

GUAVA

Three kinds of guava may attract the attention of the visitor to the Park. All belong to the group called *Psidium* which belongs to the *Myrtaceae* or Myrtle Family. None are native to the Hawaiian Islands. They are native to tropical America.



(Photo by Senda, Broadbent and Degener.)

FIGURE 41.—A typical thicket of the Malabar melastome.

The common guava, *Psidium guajava* L., shown on Plate 63, was introduced probably first on Oahu by Don Marin, the Spaniard who settled in the Islands in 1791 and died here in 1837. Now it is found throughout the Hawaiian Islands where it has formed considerable thickets at the lower elevations. Thousands of plants are seen in driving to either one of the sections of the



PLANT 63—Common Guava of Kurewa (Common)

National Park. Few plants are known within the boundaries of the Park, most of them growing near the Sulphur Bank on the rim of Kilauea Crater and near Alealea Crater toward the sea. The former location is apparently about the highest elevation at which this particular kind of guava can live, only those growing near the warm volcanic vapors bearing abundant fruit.

The common guava is a very variable shrub or small tree five to fifteen feet high. Its trunk and older branches are covered with light brown bark that scales off here and there in irregular patches to expose the greenish layers beneath. These then gradually change through yellow to brown and, in turn, fall away. The twigs, as the drawing shows, are square in cross section and bear large leaves and small, white flowers. These have numerous spreading stamens. The fruit of the guava is about three inches long and varies from ovoid to pear-shaped. It is yellow and either smooth or somewhat rough in surface texture. It contains pale yellow to pink flesh in which numerous hard seeds are imbedded. This flesh is extremely sour on some plants while on others, especially those bearing fruits with rough rinds, it is sweet. It can be eaten raw, though most of it is consumed in the form of guava jelly. This fruit is one of the favorite foods of the maggot of the introduced Mediterranean fruit-fly, a very serious pest of African origin.

The strawberry guava, *Psidium Cattleianum* Sabine, is more hardy than the common guava and is therefore more numerous in certain localities at higher elevations where the common kind is rare. The strawberry guava may be found near Glenwood, a village located between Hilo and Kilauea. This plant is a small tree that bears smooth, shiny leaves. Its fruit is red, about the size of a large cherry, and has a juicy pulp somewhat resembling a strawberry in flavor. A yellow-fruited variety, known as *Psidium Cattleianum* var. *lucidum*, grows in the same locality. Both are called *waiawi* by the Hawaiians. The name of the common guava has been corrupted into Hawaiian as *kuawa*.

OHIA LEHUA

The plant known by the Hawaiian name of *ohia lehua* is the commonest tree in the Kilauea Section of Hawaii National Park. It may be recognized by its clusters of scarlet flowers bearing numerous long stamens. Its flower structure is thus similar to



PLATE 64.—Ohia Lehua. (Original).

that of the guava (Plate 63), eucalyptus, rose apple and mountain apple, and indicates that all these plants belong to the *Myrtaceae* or Myrtle Family.

Ohia lehua trees are found throughout Polynesia, where they grow from sea level to the summits of all but the highest mountains. In the Hawaiian Islands the plants are so extremely variable in size, leaf-shape, presence or absence of hair, and other features that botanists are still puzzled as to the exact number of kinds found here. It is quite likely that only a few distinct kinds exist but that, due to cross-pollination, many variable hybrids result that are mistaken for additional distinct kinds.

The *ohia lehua* (Plate 64) found in the vicinity of Kilauea is commonly called *Metrosideros collina* var. *polymorpha* (Gaud.) Rock by botanists. It is usually a small tree or even a shrub, often germinating on the hairy stumps of ferns. The sadleria fern (p. 37), one of the earliest plants to grow on recently cooled lava flows in Hawaii, furnishes a ready means for it to establish itself in such inhospitable places. The tree ferns (p. 27) frequently have *ohia lehua* seedlings growing on their trunks, even at a height of twenty or more feet. As these increase in size, their roots partly enwrap and strangle the tree fern in their quest for the ground. The fern gradually decays, leaving the *ohia lehua* standing on stilt roots in its place. Because of this habit of the *ohia lehua* to grow epiphytically on tree ferns, the early Hawaiians believed that the fern was its parent.

The flowers of the *ohia lehua*, which in exceptional cases may vary from the usual scarlet to yellow, were formerly much used by the Hawaiians in the weaving of garlands, or *lei*. As the flower was considered sacred to Pélé, goddess of volcanoes, these garlands were supposed to be her favorite kind. In the native "Song of the *Lei* of the Hawaiian Islands," the flower is mentioned as being emblematic of the Island of Hawaii, as is the capsule of the *mokihana* (p. 193), of Kauai. When a group of natives went into the mountains for the flowers, they seldom gathered them except on the return journey because of the superstition that otherwise mist would envelop and bewilder them. These flowers secrete abundant nectar upon which the *apapane* (*Himatione sanguinea* Forst.) and many other birds feed. The *apapane* is one of the more common native birds of the Park. It can be recognized

by its scarlet body, black wings and tail, and peculiar whirring noise made by its wings when in flight.

The wood of the *ohia lehua* is hard, durable and dark. In the manufacture of the outrigger canoe, one of which is shown in figure 35 and described on page 175, it was used for the gunwale, or part called *moo*, where the paddle usually rubs. If a less durable wood were used, the canoe would soon show wear in that region. The *ohia lehua* was commonly made into bowls (Fig. 42) of the less valued kind and into *poi* boards (Fig. 22), or troughs. It was also commonly used for carving idols and for building *heiau*, or temples. These idols were not considered gods but were thought to represent them after certain ceremonies had been performed. The following account by Captain Wilkes of the United States Exploring Expedition, may be considered typical of the elaborate ceremony that was performed by Kamehameha in building the *heiau* in Kohala on the Island of Hawaii, just previous to his conquest of Oahu:

"On the 27th (Kane) of January (Kaulua), the ceremony began.

"On the 28th, a calabash of red ochre was mixed.

"On the 29th, the priest, leaning on a spear, repeats prayers and begs lands.

"On the 30th, palm leaves are spread on the roof of the house in the *heiau*.

"On the first day of the month (Nana), the people are placed in eight rows, when prayers and benedictions are offered, together with a sacrifice of pigs and fruit. Then the priest of Nukuokea appears, and asks of the king an offering of three fowls to bake at night; one for the king, one for the priest, and one for the god.

"On the second day, they go to the mountains in search of the okea [*ohia lehua*] idol, when a man was killed: at the time of the cutting down the okea [*ohia lehua*] tree the priest prayed for land, and the sacrifice was offered, with a hog and tapas, and the image carved; the direction in which the tree fell, land was sought for, and the people on it were stripped of all they had and killed; when the company returned home bearing the image and singing, 'Kuamu. Kuawa, wa—Kuawuwa la[n]akila la Uwa.' After prayers the priests each take a fowl, the chief two, and two are given to the god Kaili: these are eaten by them, the god's by his keeper,

after which they went to sleep. If it rained during the night, it was considered a good omen.

"On the third day, at an early hour, the people came with materials for building a house during the day. After the frame is set up, the people are placed in rows, and prayers are said. The idols were then carried in procession, prayers said, and they were placed around. The priest and chief exchange their wreaths of okea [*ohia lehua*] flowers, at which time the people made sixteen exclamations; the people then eat, and finish the house afterwards, which is done with much ceremony. In the evening the high-priest arrived with three fowls; one for the god, another for the king, and a third for himself. If rain fell during the night, they would conquer their enemies.

"On the fourth day, before it was light, the 'Aha' and 'Kaili' prayers were said, at which time the priest brands the land that they are to conquer. After this, the chief brings a hog, holding his snout, when the priest again prays to the idol; the chief repeating his 'Amama,' (invocation) killed the hog. The priest cautiously asks the chief if he heard any noise, or voice of a mouse [rat was meant], dog, or bird: if none, it was a good omen. Then the chief and priest advance towards the people, the former wearing a feather cloak, while the latter was naked, who demanded of the people if they heard any noise; and being answered in the negative, the priest then said the god had declared they should eat of the fruit of the land of the enemies. At night nine hogs are offered.

"The fifth day opens with prayer. The king or chief gives forty hogs for each end of the temple. In the evening, the idol they had hewn out of the tree was brought down to the temple, and placed in front of the steps of the heiau. A large hole was then dug, and a man sacrificed and placed in it; on this the idol is put, and the earth thrown in around it: the multitude now retire. The priest now demanded of the king three fowls—one for the god, another for the king, and the third for himself. The god's is devoured by his keeper, while the king and priest feast on theirs, when they all go to sleep, under the impression that some omen will occur. If rain, with thunder and lightning, ensue, the omen is very favourable.

"Just before dawn, the feather god, Kaili, with a hog, is taken to the new idol, where, on a signal being given, the king kills the

hog with a single blow; the priest strikes a few blows on the drum, which was the signal that the ceremony was finished. After this the taboo was removed, when children might cry, the cocks crow, and crickets chirp, without danger; then all the priests assemble within the heiau, and prayed in concert till daylight, at which time the king makes the 'Amama.'

"On the sixth day, the king presented a hog to each god, frequently to the number of forty, and two to each priest, two of which were placed in front of the new idol, with cocoa-nuts and bananas, where they are left to putrefy. The king and priest then retired to the 'Nule-Pahu,' where they prayed. At nightfall, one of the priests went out in search of a fish called 'olua' [*ulua*], which is represented as a fathom in length; if this fish could not be found, a man, who had broken the taboo, was hooked in the mouth, killed, and dragged to the altar; if the observance of the taboo had been very strict, and none was found delinquent, a squirrel [rat was meant] was substituted, and was offered to the idol in like manner. If a man was sacrificed, the king took hold of one of the feet of both the hog and man, and thus presented them to the god, saying, 'Here is my offering to you; let me live; let me have the country I desire to conquer.'" They then all retire and feast. A chief, called the 'Turtle,' then came forward, and prayed with uplifted hands. If any one offended by making a noise, he was instantly killed. The women afterwards brought their tax of tapa, which is put into the fifth house in the heiau.

"On the seventh day, they all bathed; after which they were all clothed in new maros [*malo*] from the tapas; they then sat down in rows, placing themselves in various attitudes, with the hands raised up or placed on their shoulders, and each was obliged to remain in the same attitude until the ceremony of prayer was concluded. Afterwards eighty hogs were distributed among the people. They then repeated the 'Aha' and the 'Kaili,' the prayers before spoken of; and the favorite wife of the king then came with a hog and fine mat, which she offered, with prayers and the 'Amama,' and requested that she might live and be preserved by the king.

"On the eighth day, the whole ceremony was finished, all the taboo removed, and a general council of the chiefs held, as to the mode of carrying on the war, when they went to conquer the land

they had sacrificed and prayed for. After the wars were ended, heiaus for peace and the prosperity of the kingdom were built, to insure fertility and plenty to the land."

The *ohia lehua* was an ingredient of a favorite Hawaiian tonic. The young leaves were used and mixed with the bark of the root of the *uhaloa* (*Waltheria americana* L.), the fruit of the *noni* (p. 282), and the leaves of the oxalis. To this was added Hawaiian sugar cane (p. 56) for sweetening. After this material had been mashed, its juice was squeezed into a calabash. As the Hawaiians could not place this wooden vessel on the fire for fear of destroying it, they resorted to dropping hot stones into it to bring the medicine to a boil. This was then administered to the patient in three doses at intervals of several days. It induced drowsiness.

The young leaves were also used as one of several remedies for thrush (p. 20), a common disease of children. The leaves were fed to the sick infant in the regular manner in which all small children were fed solid food. They were chewed by the mother and the thoroughly masticated morsel then offered to the sick child by mouth.

Today the wood of the *ohia lehua* is used for panels and floors because of its beautiful grain and reddish color. It is also suitable for railroad ties and for fuel. Ukulele keys are made from it because these do not slip as easily in their sockets as do those made of most other woods.

EVENING PRIMROSE AND FUCHSIA

Throughout the Kilauea region and within the Crater of Haleakala grows a tall herb (Plate 65), called *Raimannia odorata* (Jacq.) Sprague & Riley, with large, sulphur-yellow flowers that turn reddish on wilting. This is a South American evening primrose, belonging to the *Onagraceae* or Evening Primrose Family. It is said the plant was purposely introduced by a former Volcano House gardener, as an ornamental in 1921. By the following year, it had already escaped from cultivation and begun to spread into neighboring fields and roadsides. A smaller evening primrose appeared near the hotel vegetable gardens in 1928 and has become completely naturalized. It is almost certain that this plant gained access to this locality in impure garden seed. The smaller evening primrose, if not the larger one as well, should at



PLATE 65.—Evening Primrose. (Original).

least be eradicated from the Islands before it has had time to spread and to crowd more desirable plants out of existence.

The larger evening primrose bears a flower on an intermediate stage of evolutionary development. The more primitive flowers bear free sepals and petals which are attached to the base of the pistil which they surround. In the evening primrose, however, both petals and sepals have united with one another for more than half their length. They have grown firmly around the base of the pistil and then extend beyond it as a slender tube. Even the lower halves of the stamens have so firmly united with this tube that their presence is indicated by mere lines. In still more highly evolved flowers, like those of the morning-glory, the petals have become united to their very tips to form a funnel-shaped corolla.

The evening primrose, as its name in part implies, blooms during the night, the flowers withering or closing in the late morning as do those of the silene (p. 154). They are yellow, as that color, or white, is about the most conspicuous in the dark. In addition to their bright color, they emit an odor. Hence moths and similar nocturnal insects in search of nectar, may see the flowers at night if flying in the neighborhood, or may smell them if flying at a distance. As the nectar, however, is contained at the base of the narrow tube, almost one inch long, formed by the united sepals, petals and stamens, only moths with incredibly long tongues can reach it. As they fly from flower to flower to satisfy their hunger, they may effect cross-pollination and thus make it possible for the plant to mature vigorous seed. These are shed from the dry, capsular fruit by its splitting into four parts.

Along the roadside and in the gardens near Kilauea grow several shrubby fuchsias of hybrid origin. These plants, native to America, were introduced by the late W. M. Giffard before 1910. Though bearing waxy, crimson or purplish flowers and producing oblong, juicy berries, one can see from their fundamental flower structure that they belong to the same family as the evening primrose.

GUNNERA OR APÉAPE

In taking the beautiful but usually wet Olinda Pipe-Line Trail into the rain forest on the northeast slope of Haleakala, Island of Maui, one will see in some of the ravines a giant herb (Plate 66), *Gunnera petaloidea* Gaud., the *apéapé* of the Hawaiians. This

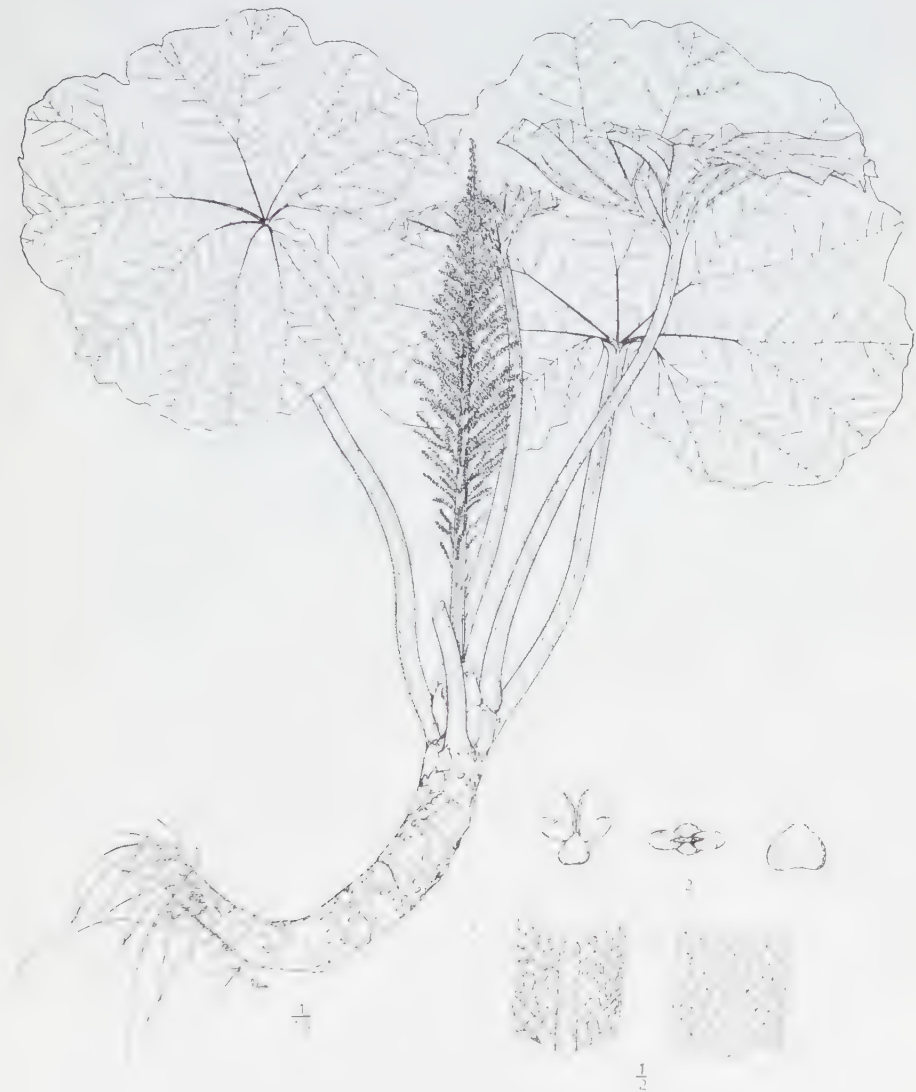


PLATE 66.—*Gunnera* or Apéapé. (Original).

particular kind of *Gunnera* is found only in these islands. It belongs to the *Haloragidaceae* or Water-Milfoil Family.

The plant is remarkable. It consists of a massive, herbaceous stem. In younger plants this is short and erect, but in older ones it sprawls over the ground for many feet before rising. Within this stem are various cavities harboring colonies of the unicellular *Nostoc gunnerae* Reinke var., a member of the *Myxophyceae* or Blue-Green Algae. As the stem of the *apéapé* increases in length, the oldest part tends to die with age. To make up for the loss of the original root attached to it, new roots form near the old leaf scars. The petioles or leaf-stalks are one to several feet long and bear at their apex the enormous kidney-shaped part of the leaf, known as the blade. This may be two to three or more feet in diameter. It is so large that it can be made to serve as an umbrella. In the center of these leaves arises the tall flower stalk. This is yellowish to brownish-orange in color and bears thousands of small, wind-pollinated flowers.

The only known near relative of the *apéapé* in these islands is the introduced marsh plant called parrot's feather, or *Myriophyllum proserpinacoides* Gill. It was found naturalized in certain marshes near sea level by the writer several years ago. This delicate herb is extensively used as an aquarium plant on the continent. The *apé* of the Hawaiians is not related to *Gunnera* but to taro (p. 79), a member of the Arum Family.

OHELO AND RELATED PLANTS

The group of plants scientifically known as *Vaccinium* and belonging to the *Ericaceae*, or Heath Family, comprises the huckleberry, blueberry, cranberry and less well-known plants of the continents, and the *ohelo* and its relatives of the Hawaiian Islands. Exactly how many of this group are native to these islands is not definitely known. All local plants belonging to *Vaccinium* are shrubs bearing simple leaves, small flowers, and fleshy berries of various shades of red.

The *ohelo*, *Vaccinium reticulatum* Smith, is found only on the Island of Hawaii and on East Maui where it thrives on the less weathered lava flows and beds of volcanic ash and cinders. It is very common in the neighborhood of Kilauea, and on the upper slopes of Haleakala, as well as within that crater near Koolau Gap. On the lower slope of Haleakala southeast of Ulupalakua,



PLATE 67.—Ohelo. (Original).

it may be found only on a small *aa* (p. 15) lava flow, the surrounding country being devoid of these plants. This shows that the typical *ohelo* is apparently rather particular in its soil requirements.

The *ohelo* is a variable shrub rarely attaining a height of two feet. Its leaves are rather leathery and often almost orbicular in outline, as the drawing of a Kilauea plant on Plate 67 shows. Some of the leaves, however, are oblong and may be either minutely hairy or practically smooth. Its clustered flowers are usually a brilliant red. All borne on the same plant develop, with very few exceptions, into fruit at the same time. It is therefore rather difficult to find a single branch suitable for illustration bearing both flowers and fruit. Many plants bearing only flowers may be found, however, within a few feet of others that bear abundant fruit and no flowers.

As one walks from the ash plain near the Sulphur Bank toward the moss-covered ground of the Tree Fern Forest, one will notice that the *ohelo* plants gradually change in appearance. The plants tend to be more slender and to bear hard, leathery leaves. These are recurved along their sharply toothed margins and are rather hairy on the lower side. The berries, instead of being depressed-globose, are somewhat elongated. This latter plant has been named *Vaccinium pahalae* Skottsberg. That this plant is sufficiently different from the *ohelo* growing near Kilauea to bear this distinctive name is not absolutely certain. This question can be settled best by planting samples of the Sulphur Bank plants in the Tree Fern Forest and some plants from the latter locality at the Sulphur Bank. If both types retain their definite characteristics, we shall know that we are dealing with two distinct kinds of *ohelo*. If, on the other hand, these features become modified because of a change in the environment, we shall know that *V. pahalae* is identical with *V. reticulatum* or but a variety of it.

The typical Kilauea *ohelo* berries are globose, with usually somewhat flattened top and bottom. They vary from a dark red to a pale yellow, and may or may not be covered with a bloom. They may be eaten raw or cooked in the form of pies or sauces. It is permitted to gather these berries, as well as the introduced thimbleberry (p. 170), blackberry (p. 170), and *poha* (p. 257), within the boundaries of the National Park provided they are eaten there. It is an infringement of the Park regulations,



PLATE 68.—Obelo Kaulaau. (Original).

however, to break their branches or to destroy or injure any kind of plant whatever.

The high-bush *ohelo*, or *ohelo kaulaau* of the Hawaiians, is *Vaccinium calycinum* Smith (Plate 68). It may be found on all the larger islands of this group in the more open rain forest. It is rather common in the forest east of Kilauea on Hawaii as well as below the Koolau Gap of Haleakala Crater on Maui. This plant can be readily distinguished from other plants of the same group by its height of three to six feet or more, by its large, relatively thin leaves, by its greenish flowers, and by its bitter berries. The latter are sometimes added in small numbers to the true *ohelo* berry before cooking to impart a special flavor to them.

Kilauea was always an object of awe to the natives as it was considered the home of Pélé, goddess of Hawaiian volcanoes. When in the vicinity of the crater, the Hawaiians were formerly careful not to strike the ground nor to dig in it for fear of disturbing her. They offered locks of human hair to her and threw both live and cooked pigs and vegetables into the molten lava to appease her anger. The worshippers of Pélé even cast the corpses or some of the bones of their deceased relatives into the crater. They were under the impression that the spirits of their dead would then be admitted to the society of the various deities living in the volcano and would use their influence in guarding their friends from lava flows and other volcanic dangers. Accounts that living human beings were immolated are, however, contradictory. The *ohelo* was a plant especially sacred to Pélé. It was therefore customary on arriving at the crater to break a branch bearing the berries and, while facing the center of volcanic activity, to throw half of the branch over the cliff, saying, "Pélé, here are thy *ohelo*. I offer some to thee; some I also eat." Only after this rite had been performed could the visitor eat freely of the berries without danger of incurring her wrath.

Though the Hawaiians had officially abolished the *kapu* (p. 109) system and their religious practices before the coming of the American missionaries, many still adhered to the old customs. Kapiolani (p. 111), a high chiefess, in December, 1824, dramatically weakened the superstitious beliefs remaining. In spite of the entreaties of her husband and her friends to give up the undertaking which appeared so dangerous to them, she set out from Kaawaloa, where Captain Cook was slain, for Kilauea with a

following of about eighty natives. She made the greater part of this one hundred mile journey over rugged lava flows on foot. Reaching the vicinity of the crater, a priestess from one of the three *heiau* dedicated to Pélé met her. She threatened Kapiolani with the displeasure of the goddess if she were to approach the crater and predicted her death if she violated any *kapu*. Kapiolani, instead of being discouraged from completing her mission, discomfited the priestess with arguments and kept on toward the crater. Here a hut, or *hale*, probably of *amaunau* (p. 39) fern, as customary, was built for her, and she and her followers passed the night. The following morning she descended about 500 feet to a black ledge, no longer existent in Kilauea today, to be in closest proximity to the swirling lava and its fountains. Here Kapiolani insulted the goddess by hurling stones into the pit and eating the sacred *ohelo* berries without first making the required offering. Then she addressed her company, "Jehovah is my God. He kindled these fires. I fear not Pélé. If I perish by the anger of Pélé, then you may fear the power of Pélé; but if I trust in Jehovah, and He shall save me from the wrath of Pélé when I break through her *kapu*, then you must fear and serve the Lord Jehovah. All the gods of Hawaii are vain." After singing a hymn, the company set out for Hilo. Only after considering with what fear the natives had regarded Pélé can one justly evaluate the great courage of Kapiolani and her followers.

PUKEAWE

Two closely related and rather variable plants belonging to the group called *Cyathodes* are native to the Hawaiian Islands. One or both kinds grow from an elevation of 2,000 feet almost to the summits of the highest mountains. They thrive on the arid lava flows as well as in the more open rain forest or in mountain bogs. Although they very superficially resemble heather, they do not belong to the Heath Family but to the *Epacridaceae* or *Epacris* family which is native mainly to Australia.

The *cyathodes* found in the Hawaiian Islands are shrubs or even small trees bearing small, stiff leaves, inconspicuous flowers and very showy, rather dry fruits. These are about a quarter of an inch in diameter and may be white, pink or dark red. The Hawaiian names for all these plants are *pukeawe*, *puakeawe*, *maiele*, *maieli* or *kaewau*. Technically, the plant growing in the

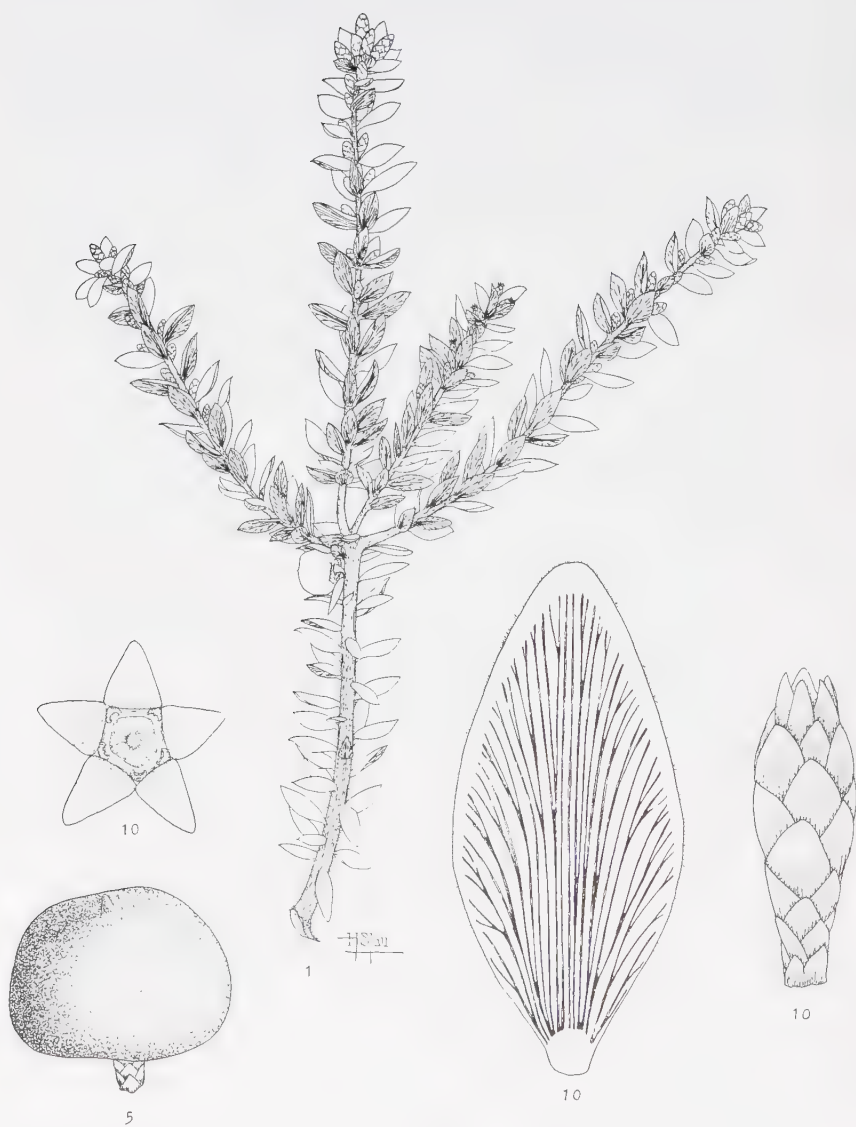


PLATE 69.—Pukeawe. (Original).

vicinity of Kilauea, here figured (Plate 69), is known as *Cyathodes Tameiameiae* Cham. It was named in honor of the famous Kamehameha who united the Islands into one kingdom under his rule. The unusual spelling of his name is due to the fact that the letters t and k are more or less interchangeable in the Hawaiian language. As at Kilauea, this plant develops into a shrub three to five feet high on the drier slopes of Haleakala. In the rain forest along the Olinda Pipe-Line Trail, however, it may reach a height of fifteen feet. On the higher regions of Mauna Loa and Haleakala may be found the closely related plant named *Cyathodes imbricata* Stschegleew. This is described as a trailing shrub bearing leaves whose veins rarely divide.

The bright fruits of the *pukeawe* are added by the Hawaiians to their *lei*, or garlands, to give them color. In the early days the entire plant was held in high esteem. According to N. B. Emerson, "When a kapu-chief found it convenient to lay aside his dread exclusiveness for a time, that he might perhaps mingle with people on equal terms without injury to them or to himself, it was the custom for him—and according to one authority those with whom he intended to mingle joined with him in the ceremony—to shut himself into a little house and smudge himself with the smoke from a fire of the *Pukeawe*. At the conclusion of this fumigation a priest recited a *pule huikala*, a prayer for a dispensation."

SUTTONIA OR KOLEA

Many peculiar kinds of *suttonia* are found in the Hawaiian Islands and not elsewhere. They belong to the *Myrsinaceae* or *Myrsine* Family. All the local ones are trees bearing thick leaves with rather smooth margins. The small, inconspicuous flowers, which are borne on stalks, are clustered in the axils of leaves that usually soon fall. The fruits are almost always globose, about an eighth of an inch in diameter, yellowish, brown or usually black, and contain a single large seed.

Suttonia Lessertiana (A. DC.) Mez may be found in the forests of Kilauea, from which the figured specimen (Plate 70) was derived, as well as on Haleakala. It is characterized by thick leaves which are about four inches long and wedge-shaped at the base. With a lens one may discern resin glands and ducts on their under surfaces, as the enlarged drawing shows. These leaves are

PLATE 70.—*Suttonia* or *Kolea*. (Original).

frequently red in color when young. The fruits are reddish to black.

Another suttonia that may be found within the boundary of the Park, especially near Makaopuhi Crater in the Kilauea Section, is *S. sandwicensis* (A. DC.) Mez. This can be distinguished from all other related plants by its small leaves which are less than one inch long. Besides these two kinds, several other suttonia possibly may be seen by the visitor who makes a special search of them. *S. lanaiensis* (Hilleb.) Mez, *S. spathulata* Rock and *S. volcanica* var. *lavarum* Rock may be found on Haleakala on the Island of Maui, while *S. volcanica* Rock may be found on Mauna Loa on the Island of Hawaii.

The Hawaiians named all suttonia *kolca*. They formerly employed the wood for the posts and beams of their grass huts, and for kapa logs, *kua kuku*. They also collected the red sap that freely exudes from incisions made into the bark and used this to dye their *kapa* (p. 137). More commonly, however, the bark stripped from the trunk of the tree was pounded and then placed in a calabash with water. After straining through coconut fiber or some similar material, the resulting liquid constituted the dye. Charcoal derived from the plant was likewise used in making a dye.

MAILE

The *maile* (Plate 71) of the Hawaiians is botanically known as *Gynopogon olivaceiformis* (Gaud.) Heller. It is found in the forests on all islands of this group in several varieties or forms, the figured specimen coming from the forest near Kilauea. These plants are not found elsewhere. They belong to the *Apocynaceae* or Oleander Family.

The *maile* is a straggling or weakly twining shrub emitting, like the plumeria, milky juice when wounded. It bears smooth, shiny leaves that are arranged in twos, threes or fours. The flowers are small, yellow, and in structure somewhat resemble those of the plumeria. They consist of five minute sepals, five petals that have grown together for the greater part of their length, five minute stamens that have partly grown to the united petals, and two carpels. These last are very peculiar. They are separate, or free, below but firmly united above. After the flowers have become pollinated by some insect, these carpels increase in



PLATE 71.—Maile. (Original).

size with the development of the seeds. The result is that the matured carpels, now called fruits, may consist of a single ring of beads, or breaking apart above, may appear as two diverging rows of beads. This moniliform, or bead-like, effect is caused by the enormous swelling of each seed, which naturally must distend the old carpel wall surrounding it. The walls between the seeds, on the contrary, remain little changed. The resulting odd fruiting-structure is well shown near the center of the plate, while toward the extreme left may be seen single fruiting segments that have not yet fallen to the ground like their erstwhile neighbors.

The *maile* was one of the favorite plants of the Hawaiians and is still much used in combination with other plants in the weaving of *lei*, or garlands. For that purpose the long leafy branches are divested of their wood. This is easily accomplished in the young twigs by merely loosening and freeing the bark from the base, winding it a few times around the exposed wood of the stem, and then quickly pulling the slippery wood out of the surrounding bark. In the older stems, however, the bark must first be loosened from the wood for its entire length before it can be drawn away. This one can usually see the *lei* women doing with their teeth. When a *maile lei* is fresh, its odor is not so noticeable as when it begins to wilt.

In the early days during war times if an armistice were desired, the contending chiefs met in a *hciau* and there wove together a *lei* from the branches of the *maile*. When the *lei* was completed, heralds announced the news to the populace. The fresh leaves of the *maile* and other fragrant material were often placed in calabashes where the *kapa* was kept to perfume it. *Maile* was also used medicinally. In the *halau* (p. 53) it was one of the common decorative plants.

LANTANA

The lantana (Plate 72), botanically known as *Lantana camara* L., belongs to the *Verbenaceae* or Vervain Family. Its Hawaiian name, a modification of the English, is *lakana*. It is a variable plant native to tropical continental America. Unfortunately it has been introduced as an ornamental in many warm countries because of its colorful flower clusters. It usually escapes from the garden and shortly overruns the country to become an extremely costly and

PLATE 72.—*Lantana* or *Lakana*. (Original).

troublesome weed. It was purposely introduced as a garden plant into the Hawaiian Islands in 1858. Various birds, especially the false myna or Indian starling, feed on its berry-like fruits. As the contained seeds pass unharmed through their digestive tract, the plants spread rapidly as soon as the false myna was brought to the Islands. Now lantana may be found throughout the lowlands in dry as well as moist localities. The plant became such an objectionable pest that in 1902 eight different kinds of lantana-feeding insects were introduced from Mexico to check its growth. These, in conjunction with the lantana scale-insect accidentally introduced before that date, have almost exterminated the plant in a few localities. Recently a second kind of lantana was introduced as an ornamental. It is to be hoped that this will not, likewise, become a pest.

The lantana is a shrub ordinarily two to five feet high, but in particularly favorable situations where other plants may lend it support, it may attain a height of fifteen feet or more. Like most members of the Vervain and Mint Families, the lantana bears a square stem. This, in the particular form brought to the Hawaiian Islands, is armed with sharp, recurved prickles. Some people are slightly poisoned by scratches made by them. The stem bears its leaves in opposite arrangement. These leaves are rough to the touch, especially on the upper surface, and when bruised emit a penetrating, aromatic odor. From their axils frequently arise peduncles, or stalks, bearing a single flower cluster at their ends. The flower-buds on the periphery of the cluster are the oldest. As they begin to bloom, they are usually orange in color. With age they become pink, while the younger buds adjoining them in turn become orange. Thus a vigorously blooming cluster exhibits two colors: pink near its edges and orange in its center. These flowers at length develop into small, blue fruits (Plate 72, at right).

Just as a detailed study of the buttercup flower (Fig. 34, E) explains the fundamental plan upon which all Hawaiian flowers are built, so a comparison of the flower cluster of the lantana with the complex "head" or capitulum of the *kokoolau* (p. 295) explains how that highly specialized structure typical of the Composite Family may have arisen. The flower cluster of the lantana, for example, is essentially a greatly modified twig bearing a group of degenerated leaves, each with a small flower in its axil. This twig, instead of growing in length to scatter its leaves and flowers

along a distance of a foot or more, has become arrested in growth just as soon as the minimum space sufficient for their development has arisen. Hence it is but a fraction of an inch in length and bears the small flowers and yet smaller leaves in an almost flat, circular group. The youngest leaves and flowers, being at the tip of the shortened twig, are naturally at the center of the cluster, while the older are arranged, in order of their age, around them. The highly specialized flower cluster or "head" of the *kokoolau*, as explained on page 295, might have been derived by further specialization from a cluster of flowers similar to that of the lantana. This can be visualized best by comparing the cross section of the one with that of the other (Fig. 45).

PRUNELLA OR SELFHEAL

One of the very common weeds of lawns and waste places in North America is the selfheal (Plate 73) or *Prunella vulgaris* L., a member of the *Labiatae* or Mint Family. This is actually a Eurasian plant that accidentally reached America in the early days. In 1927 the writer found this same plant growing in great numbers on the cattle ranges of Haleakala as well as within the crater itself. At that time it was also observed in the rain forest, but only along the Olinda Pipe-Line Trail and along the mountain torrents. It is probable that saddle horses passing along this trail carry the seed-like nutlets of the plant on their hoofs and thus cause wide dissemination; and the nutlets of plants growing at the sources of the Haleakala streams are carried by the water to find final resting places, perhaps suitable for growth, here and there along their banks. It is not known whether this plant reached these islands with impure garden or grass seed or whether it arrived in cattle fodder from the coast.

The selfheal is an herb two inches to almost two feet high, bearing small, opposite leaves. Its upright stem terminates in a dense cluster of purple to blue flowers. Each flower bears five unequal petals, all of which have grown together at the base to form a tube. In addition to that, two of these have united to their very ends. In this way, they form a hood to protect the four stamens that lie beneath them.

The selfheal was used medicinally by the Europeans in the early days, but is now considered a worthless weed.



PLATE 73.—*Prunella* or *Selfheal*. (Original).



PLATE 74.—Cape Gooseberry or Poha. (Original).

CAPE GOOSEBERRY OR POHA

The Cape gooseberry (Plate 74), known locally by the Hawaiian name of *poha*, is botanically *Physalis peruviana* L. It is not a gooseberry but a member of the *Solanaceae* or Nightshade Family to which the potato and tomato belong. The plant is native to Brazil but was introduced into the Islands previous to 1825. Now it is one of the more common plants along roadsides and in clearings from 1,000 to 8,000 feet elevation. It is very common in the Kipuka Puauolu near Kilauea as well as within the Crater of Haleakala. Even as early as 1840, Commander Wilkes of the United States Exploring Expedition reported it as common near Napau Crater, not far from Kilauea. Though the fruit of this plant are very palatable, he notes that "The natives do not make any use of them, and seemed quite surprised to see us eat them."

The *poha* is a coarse herb becoming two to three feet high. Its hairy leaves are not strictly opposite but are usually borne in pairs, one of the two leaves being smaller than the other. This unusual condition is caused by the intimate union of the larger leaf with the main stem up to the next higher node. The axillary flowers are yellow with a brownish eye. As these develop into fruit, the calyx inflates and increases enormously in size. The result of this development is that the delicious, yellow, tomato-like fruit is protected from injury and dirt by a paper-like bag, as the longitudinal section of one of them shows on Plate 74.

The fruit of the *poha* may be eaten raw. It is, however, best cooked to a jam or jelly. This has a very distinctive flavor.

POPOLO, POTATO, AND JERUSALEM-CHERRY

Solanum is the scientific name for the largest group of plants belonging to the *Solanaceae* or Nightshade Family. Of this group at least three representatives may be found within the boundaries of Hawaii National Park.

The *popolo* (Plate 75) of the Hawaiians, *Solanum nigrum* L., but occasionally called *Solanum nodiflorum* Jacq., by some botanists, is of cosmopolitan distribution. It has several ill-defined varieties and forms. It is found throughout the Hawaiian Islands in clearings and waste places. Two slightly different kinds grow in the Kilauea Section of the Park, one of which is native. The plants called wonderberry and morelle are merely American and Euro-



PLATE 75.—Popolo (Original).

pean strains of *S. nigrum* which have been improved by artificial selection to increase their value as food for man.

The *popolo* is a prostrate or erect herb, varying in height from three inches to about three feet. It may be either hairy or smooth, and may bear leaves that possess even or somewhat angular margins. The plant has not only the strange leaf-arrangement found in the *poha* (p. 257) but also a very strange arrangement for its flower clusters. Each cluster develops actually in the axil of a leaf. Its basal half, however, has grown together with the main stem halfway to the next higher node. Its upper half thus extends freely from the internode into space, a very unusual position, as the plate shows. The flowers borne on these clusters are either white or lavender in color. They have a five-parted calyx which does not enlarge in fruit as does that of the *poha*. The corolla, likewise, is five-parted. After fertilization these flowers develop in time into juicy, black berries about one-fourth of an inch in diameter. These contain numerous seeds, as may be seen from the figure of a cross section of the fruit.

The fruit of the *popolo*, called *huapopolo*, was eaten by the Hawaiians. It has a peculiar flavor that is agreeable to many. The fruit was also fed to infants suffering from the disease called thrush, being used as a remedy in the same way as were the leaves of the *ohia lehua* (p. 236). The juice of the plant was used as a laxative. For a man suffering from some digestive disturbance, the bruised leaves were made into a ball and rubbed over his abdomen.

The ancient Hawaiians in times of famine throughout the Islands, or habitually in districts where taro lands were few, as between Kawaihae and Mahukona on the Island of Hawaii, gathered the leaves and young branches of the plant. These were either tied in *la-i* (p. 97) leaves or placed in calabashes before being cooked in the *imu* (p. 113). This spinach-like vegetable was then eaten with fish as a substitute for *poi* (p. 82). Young *popolo* leaves were occasionally used as a cough medicine and as a remedy for sore throat. They were either eaten raw or first wrapped in *la-i* leaves and put on charcoal to roast. The leaves, either in a dry or fresh state, were also made into a tea which was taken as a tonic. As some foreign strains of the *popolo* are distinctly poisonous, having caused the death of some who have



PLATE 76.—Jerusalem-Cherry. (Original).

eaten the fruit on the continent, visitors are cautioned against tasting any part of the plant.

The common potato, *Solanum tuberosum* L., is not native to the Hawaiian Islands but was introduced by the white man in the early days. Soon it was extensively grown on the slopes of Haleakala. It is interesting that this plant, producing abundant, poisonous, yellow, tomato-like fruits, has escaped from cultivation and now grows wild in the wet meadows of the crater near Kaupo Gap. The plant has apparently reverted to its ancestral condition.

The Jerusalem-cherry (Plate 76), *Solanum pseudo-capsicum* L., is a light green, herbaceous shrub becoming one to four feet high. It is native to the Old World but was introduced into these islands probably before 1875. It may be seen on the drier slopes of Haleakala as well as in the vicinity of the Kipuka Puauulu northwest of Kilauea. This plant is frequently grown as an ornamental in pots in temperate regions because of its small, white flowers and long-persistent, bright red berries.

BRUGMANSIA OR FLORIPONDIO

Along the roadside between Hilo and Kilauea may be seen a coarse shrub bearing enormous, white, pendent flowers. This is the floripondio (Plate 77) or *Brugmansia arborea* (L.) Steud., another member of the *Solanaceae* or Nightshade Family. Locally it is known by the less correct names of angel's trumpet, devil lily, and *Datura arborea* L. The plant is native to South America but was introduced as an ornamental into these islands before 1875. The floripondio, like its close relative, the jimson weed, contains narcotic poisons. These impart to it a tobacco-like odor when bruised.

FALSE SANDALWOOD, NAIIO OR MYOPORUM

The *naio* or false sandalwood is found exclusively in the Hawaiian Islands. Distantly related kinds, however, grow in Australia. All belong to the *Myoporaceae*, or Myoporum Family.

A study of the Hawaiian myoporum is very instructive in indicating how extremely difficult it is to write a reliable flora of these islands without conducting exhaustive field work. It is easy enough to gather together all Hawaiian plants preserved in herbaria or their photographs, to arrange all of similar appearance in separate piles, then to write a distinctive description to

PLATE 77.—*Brugmansia* or *Floripondio*. (Original).

include all plants in each pile, and finally as a climax to publish each description with a scientific name. Yet how often will such a procedure give us the true answer to the riddle of the relationship of one Hawaiian plant to another, unless performed by a foreign specialist on a definite group or two, or by a resident botanist who can devote the greater part of his life to collecting his material in the field and continuing its study in the herbarium?

To date, all Hawaiian myoporum have been passing under the name of *Myoporum sandwicense* (DC.) A. Gray, although they have significant differences. In general, at lower elevations they are small shrubby trees bearing thick, hairless, often viscid leaves lacking marginal teeth. At higher elevations, on the contrary, they are usually tall, sometimes attaining a height of fifty feet, and bear non-viscid leaves. The cause for this difference in appearance is probably an ecological one. The plants growing in the lowlands are merely dwarfed and have fleshy leaves because of their exposure to a drier and hotter environment. Because they are the same, though superficially molded each to a different form by the special environment in which they live, both types of plant must bear the same scientific name. Or if these apparent, though not actual, differences are well defined and constant under the two diverse conditions, the one ecological form, to which the type specimen does not belong, may be given a distinctive, pseudoscientific name for the sake of convenience. This name, however, must be preceded by the word "ecoform" or "eco-variety" and has no official nomenclatorial status. Thus the common false sandalwood is called *Myoporum sandwicense* (DC.) A. Gray, while the stunted, thick-leaved specimens, botanically known by the same name, might have "ecoform *crassifolia*" appended.

In studying a rather comprehensive collection of Hawaiian myoporum, one will note that plants exist with leaves either hairy, especially on their lower surfaces, or with leaf-margins serrate, or with a combination of both these characters. Such plants, as field observations prove, may be found usually in considerable numbers in widely separated regions surrounded by the typical kind similar to the one shown on Plate 78. For example, in a certain region on Hualalai on the Island of Hawaii and in one above Waikolu Valley on the Island of Molokai, the myoporum bears leaves resembling those of a peach



PLATE 78.—False Sandalwood or Naio. (Original).



PLATE 79.—Hairy False Sandalwood or Naio. (Original).

—they are smooth and have serrate margins. On Lanai a similarly unusual kind of tree may be found which, however, bears hairy leaves with serrate margins. In a certain valley on the upper slope of Haleakala near Ulupalakua, Island of Maui, grow very characteristic trees bearing hairy leaves with almost smooth margins, as Plate 79 clearly shows. On a single ridge on Molokai may be found plants which produce, especially when wounded, some branches with the smooth type of leaf and other branches with the hairy type, and both these types of leaf may have either entire or serrate margins. These two characteristics—hairiness and presence of serrations—are obviously traumatic, or wound, reversions in the Molokai plants to the ancestral state, just as the *koa* (p. 175) when wounded will produce its ancestral type of compound leaf.

From the evidence which the Molokai plants in particular furnish, we can assume with little risk of error that the ancestor of the Hawaiian myoporum, which reached these islands presumably from Australia ages ago, bore leaves having a hairy surface and a serrate margin. These features were gradually lost from visible expression as the plants became modified into the common Hawaiian plant now to be found on most of the islands of this group. These ancient leaf characteristics, however, are yet lying latent and occasionally crop out independently with various degrees of intensity in plants inhabiting different regions. Such a change or mutation may perhaps be stimulated by certain ecological conditions or may arise independently of external causes. If so distinctive a plant breeds true and persists as an element in the flora of these islands, it is deserving of a special botanical name either as a distinct form, variety, or even species. Such an example is the Haleakala plant depicted on Plate 79, which is technically described and named in the Illustrated Flora.

It is obvious that the various hairy-leaved myoporum are not necessarily closely related among themselves, nor the peach-leaved kinds among themselves. They are more likely close relatives of the common *M. sandwicense* growing in their immediate neighborhood. If the plants, on the other hand, were identical in appearance in two widely separated regions, we might suspect that these are not examples of more or less parallel progressive or regressive evolution but rather that the plants in one station had been derived

by the transport of seed from the other. This might have been accomplished by the agency of birds or in some other way. Such, however, is not true of the *myoporum* studied.

After most of the true sandalwood trees (p. 144) had been cut down for the Canton market, the Hawaiians began the export of *naio* wood as a substitute. Though the wood becomes very fragrant on drying, it did not meet with a ready sale.



(Tai Sing 1,00)

FIGURE 42.—Hawaiian village; calabashes, or *umeke*, in foreground.

The *naio* was frequently used in the building of the Hawaiian house (Fig. 42). In ancient times every man of importance was supposed to have at least five or six separate houses in his establishment. Since none of these had any partitions, such an establishment practically corresponded to a single large house containing so many separate rooms. The *hale mua* was the eating house for the men, and was distinct from that for the women because the latter were forbidden, on pain of death, to eat with adults of the opposite sex. The *hale noa* was the separate house of the wife to which, however, her husband was allowed access. The *hale aina* was the eating house of the wife, daughters, and sons up to the age of about five years. The *hale kua* was the house where the wife and daughters beat out the *kapa* (p. 132), and performed other work, while the *hale pea* was the house of separation for the wife at certain periods. The *hale heiau*, on the other hand, was the house of worship and here the family idols were kept. In certain cases the idols were not provided with a separate house but were lodged in the open, while in other cases they were kept in the *hale mua*.

From the late Director Brigham's excellent monograph on "The Ancient Hawaiian House," we learn that the natives in the early days preferred the *naio* or such trees as the *kauila* (*Alphitonia zizyphoides* (Spreng.) A. Gray p. 204, and probably *Colubrina oppositifolia* Brongn., var., p. 204) and the *mamani* (*Edwardsia chrysophylla* Salisb., p. 179) for the main timbers of their best houses. *Ohia lehua* (*Metrosideros* sps., p. 230) and inferior trees were used for the commoner ones, while the *lama*, or *clama* (*Maba* sps.), was usually used in *heiau*, or temples. Though many kinds of wood could have been used equally well in building the main frame of a single house, only one kind was used because of the superstitious fear that otherwise discord would be caused among its future inhabitants. All structures were built on the same general plan, though the building of those for the chiefs and priests was often preceded by gruesome ceremonies in their special honor. The corner posts of their structures were lowered into holes in each of which might be a man standing to encircle it with his arms. Earth was then filled in around the post and over the unfortunate victim. The death of such a sacrifice was thought to stabilize the structure. This seems to have been an almost

universal custom practiced occasionally even by the Europeans as recently as the Middle Ages.

William Ellis, who lived in the Islands about a hundred years ago, wrote the following very reliable description of the construction of the native Hawaiian house:

"They begin to build a house by planting in the ground a number of posts, six or eight inches in diameter, in a row, about three or four feet apart, which are to support one side of the house. When these are fixed in a straight line, they erect a parallel row, to form the opposite side. In the small houses, these posts are not more than three or four feet high, while in the larger ones they are twelve or fourteen feet in height, and proportionally stout. Those used in the chiefs' houses are round, straight, and smooth, being prepared with great care, but in general they are fixed in the ground without even having the bark stripped off. Grooves are cut in the top of the posts, along which small poles are laid horizontally, instead of wall-plates, and tied to the posts with the fibrous roots of the *ië* [*icie*, page 51], a tough mountain plant. A high post, notched at the top, is next fixed in the middle at each end, and supports the ridge-pole, on which the tops of the rafters rest, while, at the lower end, they are fixed on the wall-plate, each rafter being placed exactly above the post which supports the horizontal pole, or wall-plate. When the rafters are fixed, small poles are laid along, where they cross each other above the ridge pole; sometimes poles are fastened across like tie-beams, about half way up the roof, and the separate parts of the whole frame are *tied together* with strong cinet, made of the roots of the *ië* [*icie*] plant, or fibres of cocoa-nut husk. The space between the posts at the sides and ends is now closed up with sticks, larger than a common-sized walking-stick, which are tied with cinet in horizontal lines, two or three inches apart, on the outside of the posts, and extending from the ground to the top of the roof. A large house, in this stage of its erection, has a singular appearance.

"If the sides and roof are of plantain [page 108] leaf-stalks, and the leaves of the pandanus [page 47], or of ti [page 97] leaves, each leaf is wove around the horizontal sticks, which gives it a neat appearance, resembling a kind of coarse matting on the inside, while the ends of the leaves hang down without. But if

they are covered with grass, which is most commonly the case, it is bound up in small bundles, and these are tied to the small sticks, along the side of the wall of the house, with cinet or cord. They always begin at the bottom, and tie on the grass with the roots upward and inside, and continue one row above another from the ground to the top of the roof. The roof and sides are always of the same material except where the latter are of plantain or ti leaves. The corners and ridge are sometimes covered with fern leaves [*Sadleria*, page 41], with which they can secure these parts better than with grass, &c. The shell is now finished, and generally, except in the lowness of the sides and steepness of the roof, looks much like a hay-rick, particularly as they never thought of making windows, and had only one aperture, which was the entrance. . . .

"The shall of the house being finished, they proceed to fit up the inside, which is soon accomplished, as they have neither partitions nor chambers, and however large the house may be, but room and one floor. In preparing the latter, they sometimes level the ground, and spread grass over it, which they cover with large mats made of the leaves of the pandanus. But the best floors are those formed with pebbles,—which are always dry, and less likely to be infested with vermin than those covered with grass.

"The size and quality of a dwelling varies according to the rank and means of its possessor, those of the poor people being mere huts [eight or ten feet square, others twenty feet long, and ten or twelve feet wide], while the houses of the chiefs are from forty to seventy feet long. [Their houses are generally separate from each other; even in their most populous villages, however near the houses may be, they are always distinct buildings.] Although there are professed house-carpenters who excel in framing, and others who are taught to finish the corners of the house, and ridge of the roof, which but few understand, yet, in general, every man builds his own house. If it be of any size, this, to an individual or a family, is a formidable undertaking, as they have to cut down the trees in the mountains, and bring the wood from six to ten miles on their shoulders, gather the leaves or grass, braid the cinet, &c., before they can begin.

"But when a chief wants a house, he requires the labour of all who hold lands under him; and we have often been surprised

at the despatch with which a house is sometimes built. We have known the natives come with their materials in the morning, put up the frame of a middling-sized house in one day, cover it in the next, and on the third day return to their lands. Each division of people has a part of the house allotted by the chief, in proportion to its number; and it is no unusual thing to see upwards of a hundred men at a time working on one house.

"A good house, such as they build for the chiefs, will keep out the wind and rain, and last from seven to ten years. But, in general, they do not last more than five years. . . .

"When the house was finished, it was soon furnished. A sleeping mat spread on the ground, and a wooden pillow, a wicker basket or two to keep their tapa [page 132] or native cloth in, a few calabashes for water and poë [poi, page 82], and some wooden dishes, of various size and shape, together with a *haka* [Fig. 37, at right], were all they required. This latter article was sometimes like a stand used by us for hanging hats and coats on. It was often made with care, and carved, but more frequently it was a small arm of a tree, with a number of branches attached to it. These were cut off within a foot of the main stem, which was planted in some convenient part of the house, and upon these natural pegs they used to hang their calabashes, and other vessels containing food. They always sat on the ground, and took their food near the door of their house."

TRUE PLANTAIN OR LAUKAHI

The visitor to Hawaii National Park may see four or possibly a few more kinds of true plantain. All belong to the group called *Plantago* which is a subdivision of the *Plantaginaceae* or Plantain Family. Three are introduced weeds, while the others are harmless plants peculiar to these islands. Their Hawaiian name is *laukahi*, a word applied to many other plants as well. Their common English name, plantain, is unfortunately the same as that used for the cooking banana (p. 108) in some regions.

A close relative of *Plantago princeps* Cham., discovered by the writer, grows on the cliffs of Haleakala Crater near Kaupo Gap on the Island of Maui. This plant is of an archaic type, being a shrub several feet high. At the ends of its branches are borne tufts of long, narrow leaves. In their axils slender flower stalks

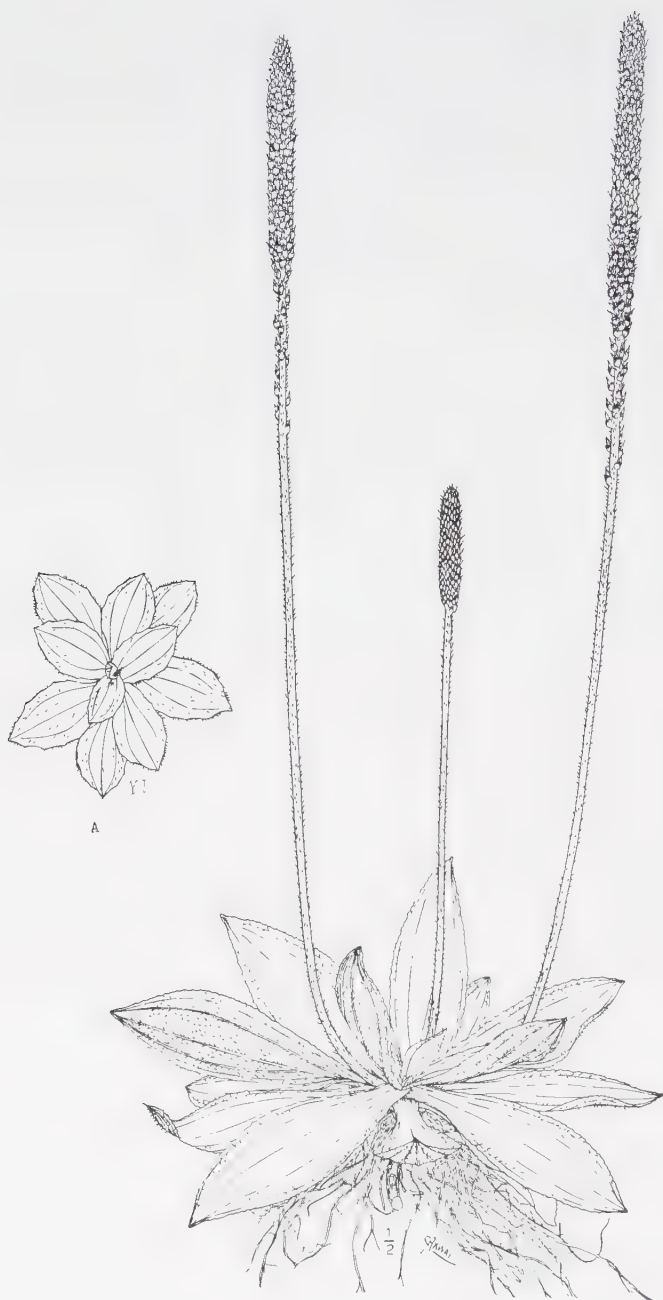


PLATE 80.—Virginia Plantain. (Original).

called spikes, occasionally develop, which are thickly beset with small, inconspicuous, wind-pollinated flowers.

Plantago pachyphylla A. Gray, the thick-leaved plantain, is a strange plant growing in great abundance in the fog-swept Koolau Gap of Haleakala Crater. This plantain is not upright but creeps along the ground, the older part of the stem gradually dying away. Only the growing end bears a tuft of leaves. Though quite variable, these leaves are usually extremely thick, and bear silky hair on the under side, at least when they are young. At flowering time, tall spikes, bearing numerous flowers, rise into the air. A similar plant, called *Plantago pachyphylla* var. *hawaiiensis* A. Gray, grows usually above 6,000 feet altitude on Mauna Kea on the Island of Hawaii.

The common plantain, *Plantago major* L., is native to parts of North America and Europe. In some unknown way it reached these islands where it was first collected in 1865 by W. T. Brigham, long Director of the Bishop Museum, and by Horace Mann Jr., the son of the famous educator. Now it may be found in both Sections of the Park in moist meadows and along roadsides. This plant is more highly evolved than the plantains previously described. Instead of producing a tall, branching stem or a long, creeping one, the stem never becomes more than a fraction of an inch in height. The delicate growing point is therefore level with the ground and protected from browsing animals while only the leaves, which can be readily replaced, are exposed to such danger. These are oval in shape and more or less upright in position. At flowering time one or more spikes arise which are from two to fifteen inches long. These bear flowers for more than half their length. The seed-bearing capsules that finally develop are surrounded by the dried corolla in an expanded state.

The Virginia plantain, *Plantago virginica* L., (Plate 80), is native to the Eastern United States. It probably reached the Island of Hawaii in impure grass seed imported from the continent. It was first collected on that island in pasture lands near Waimea in 1909. Thirteen years later it had reached the vicinity of the Volcano House at Kilauea, and at the present writing it is continuing to spread along the roads that pass through that region. The plant is partial to rather dry, barren or rocky soil. Though closely resembling the common plantain, it can be readily distin-

guished by its usually prostrate leaves, purplish spikes, and seed capsules surrounded by the persistent, closed corollas.

This plantain exhibits the rosette type of leaf arrangement so commonly seen in many herbs like the evening primrose (p. 236), *Scnccio* (p. 304) and thistle, particularly when they are yet young. As the stem is even shorter than that of the common plantain, the plant has been obliged to modify its leaves in a special way to prevent the upper ones from shading those that are beneath. This has been accomplished by successively lengthening the stalks of the lower leaves so that their blades project beyond those above them, as the smaller drawing (A) on the plate illustrates. The second difficulty that the plantain has been obliged to overcome is that of remaining at ground level and not growing above it as the stem lengthens to produce new leaves. This is accomplished by the active contracting and shortening of the root, thus pulling the leaves firmly down against the soil. As the inner, woody part of the root contracts more than the outer part, one may often see the bark adjoining the stem deeply wrinkled horizontally. The entire plant is well protected from grazing animals and from extremes of temperature and dryness by this rosette shape. At the same time, it has its leaves fully exposed to sunlight.

The lance-leaved plantain, *Plantago lancolata* L., is the third foreign plantain found in the Islands. It is a native of Eurasia but has become widely disseminated. It became naturalized in Australia many years ago and from there Gay and Robinson introduced it as an impurity in grass or flower seed around 1890. In the Kokee region on the Island of Kauai, it soon became such an aggressive weed that it threatened to displace the valuable grasses. This plant may be found in small numbers within the boundaries of the Park, particularly along trails and roads, and in moist meadows. It may be distinguished from the other plantains by its rosette type of growth, lance-shaped leaves, and spike bearing flowers only near its end.

By the Hawaiians the fresh leaves of the *laukahi* were pounded and used as a poultice, while the dried leaves were made into tea. The juice of the plant was applied to bleeding wounds to act as a styptic.



PLATE 81.—Arabian Coffee. (Original).

COFFEE

Though the coffee plant is not found within the boundaries of the National Park, it is so commonly planted in the Islands and so frequently seen by visitors that an account of it is here worthy of inclusion.

Two kinds of coffee, Arabian and Liberian, have been introduced into the Hawaiian Islands, both of African origin and both members of the *Rubiaceae*, or Coffee Family. The seed of the Liberian coffee, *Coffea liberica* Bull, were introduced into the Islands by the government in 1894 because of this plant's great resistance to a serious fungous disease and because of its adaptation to growth near sea level. It is a tree sometimes attaining a height of forty feet, bears leaves eight or more inches long, and produces flowers having six to eight petals. The plant was grown commercial in some of the valleys at the western base of Mt. Kaala, Island of Oahu. Though this planting has been long abandoned, offspring of the original trees may be found to this day growing wild in the neighborhood. The Arabian coffee and not this kind, as reported erroneously by two previous writers, is found as an escape in the vicinity of Honolulu. In spite of the relative resistance of the Liberian coffee to disease, it never gained in popularity, largely because of its inferior aroma. It is now regarded locally as little more than a curiosity.

Exactly when the Arabian coffee (Plate 81), *Coffea arabica* L., was introduced is not known. It is certain, however, that it was brought here previous to Dec. 30, 1817, because Don Francisco de Paula Marin, a Spaniard who arrived in the Islands in 1791, stated definitely in his journal, now lost, that he planted it that day. Marin, known affectionately by the Hawaiians as Marini or Manini, was a remarkable man who helped the king in many ways and was responsible for the introduction of numerous valuable plants.

John Wilkinson, a gardener whom Governor Boki (p. 146) of Oahu brought from England on the Frigate "Blonde" to develop agriculture in the Islands, gathered coffee plants in Rio de Janeiro when the vessel put into that port for fresh supplies. Thirty of the plants that survived the five-month voyage around the Cape to the Hawaiian Islands were planted probably on May 28, 1825, and became finally established on Governor Boki's

plantation in Manoa Valley near Honolulu. Although these plants were neglected after Wilkinson's death two years later, many grew to maturity and produced seed. The present coffee plantations in the Islands owe their stock almost entirely to these plants introduced from Brazil by Wilkinson and to seed introduced shortly after from the Philippines by Richard Charlton, the very troublesome and rather undiplomatic consul who was fortunately recalled by England. The plants grown by Marin had apparently died or been ignored for propagative purposes, Stephen Reynolds stating in the records of the Royal Hawaiian Agricultural Society of 1850 that if the coffee had been brought to the Islands before it had been introduced "in the 'Blonde' in 1825. . . . it had become extinct."

Due to the successful growth of the coffee in the vicinity of Honolulu, plantations were begun on the Island of Hawaii in 1828 or '29 and on Kauai in 1842. The industry was even encouraged by the king who on May 11, 1842, made the following proclamation: ". . . The officers and people are hereby informed, however, that there is a new article which is very valuable, and that is Coffee. The people will do well to pay their land tax in coffee, rather than in swine, particularly in places well adapted to the growth of coffee. And those persons who are in pursuit of wealth would do well at the present time by planting coffee. Those who raise coffee will find it the same to them as money. The price allowed for the present year will be five pounds to the dollar. But that price will not be permanent, it will fall at no distant period."

The entire coffee crop of the Hawaiian Islands was marketed locally until 1845 when 248 pounds of coffee was exported. This trade steadily increased until a shortage of labor occurred in 1849 due to the California Gold Rush, a fungus became prevalent in 1851 that attacked the trees, and a scale insect became common a few years later which further injured the plants by feeding on their sap. To show the loss to which growers were subjected by these fungi and insects, one can cite the experience of one planter in the Kona District of the Island of Hawaii. In 1858 he gathered 18,000 lbs., of coffee from his fields; in 1859 the crop was reduced to 12,000 lbs.; the following year he harvested but 5,000 lbs.; while in 1861 he was obliged to purchase coffee for his own consumption. Such difficulties finally forced many of the early

growers to cut down their plantations and to replant their land to sugar cane. Some of the old plantations, nevertheless, continued in existence and many new ones were begun from time to time in different regions. Many of these, in turn, were later abandoned for various reasons. For example, the extensive planting of coffee in the early '90s between Hilo and the Kilauea Section of the Park, for which the beautiful jungle was destroyed, proved a failure. Though the trees grew vigorously, they did not produce a paying crop, probably due to the excessive rainfall of the region. The land still shows the effects of this enterprise, as the visitor can observe, being covered with small trees and tree ferns instead of the giants of former years.

Today 95 per cent of the coffee grown in the Islands is raised between an elevation of 500 and 3,000 feet in the Kona District. The trees are usually tended by Japanese farmers in holdings of 5 to 15 acres with about 500 trees per acre. These small plantations are usually leased for a period of fifteen to twenty years. The plantings begin bearing in their third year and on the average produce a profitable crop for about thirty years, though individual trees may continue to be profitable for ten or more years longer. The area held in these trees in 1929 amounted to about 5,500 acres and produced almost eight million pounds of coffee. More than half of this was sold on the Pacific Coast, where it is used for blending with milder grades of coffee grown elsewhere.

The Arabian coffee plant is much smaller than the Liberian kind, being a slender, erect tree or large shrub rarely over 25 feet high. It produces two kinds of branches, the main one forming the upright trunk. This gives rise to lateral branches which, in turn, produce other lateral branches but normally never produce erect ones. The leaves are mostly 4 to 7 inches long, evergreen, shiny and in opposite arrangement. These bear fragrant, white flowers in their axils at certain seasons of the year, these seasons differing somewhat in the different regions in which the plants are grown. For example, on the Island of Hawaii in the Kona District they flower most abundantly in March and April and fruit in the fall, while on the same island in the Hamakua District they flower most abundantly in July and August and fruit mostly in early spring. Each flower has five petals, while the flowers of the Liberian coffee, as previously mentioned, have six to eight. About seven months after the flowers have been pollinated, they develop into oblong to globose berry-like fruits

(Plate 81, A) that vary from half to three-quarters of an inch in length. These are quite fleshy, red and shiny, and somewhat sweet. They are structurally not very different from the fruit of the cherry or peach tree and technically may therefore be called drupes rather than berries. As in the edible cherry, the outer part of the fruit is fleshy, while the inner part is hard, forming the stone, or endocarp (B). This encloses the seed, which bears a thin seed-coat. The fruit of the coffee plant is a drupe which differs primarily from the cherry in containing two separate, convex stones, each of which is horny rather than woody. To prepare these seeds, commonly termed "beans," for kitchen use, they must pass through complicated processes and be freed of their horny covering as well as of their papery seed-coat. This may be accomplished in one of two ways.

By the older method of preparing the "beans" for commercial use, the fruits were dried until brittle throughout. Then they were crushed and the naked seeds separated from the refuse. That process has been displaced by the newer, "wet" method graphically

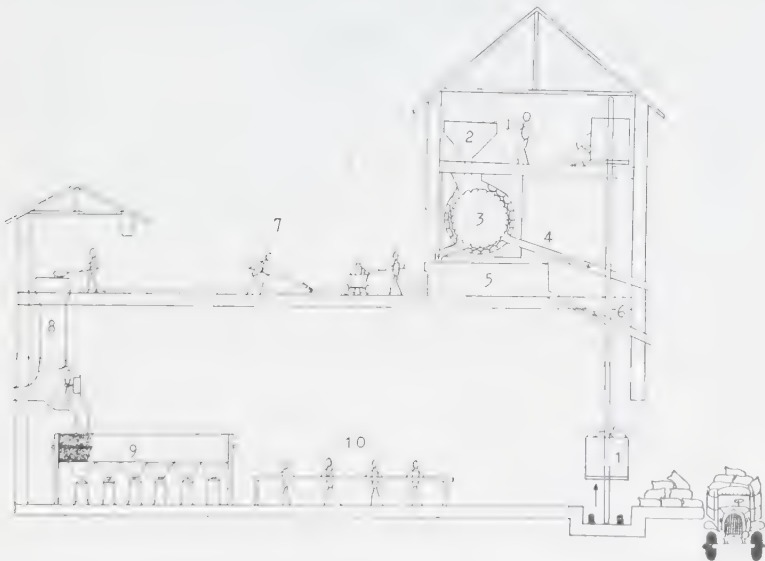


FIGURE 43.—Diagram of process for deriving "green coffee" from the coffee fruit.

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|--|--|
| 1. Elevator. | 6. Pipe for disposal of water with waste |
| 2. Feeder. | 7. Drying platform. |
| 3. Pulper for removal of flesh to expose "wet parchment" coffee. | 8. Hulling and polishing machine. |
| 4. Pipe for disposal of flesh. | 9. Grader |
| 5. Fermentation tank for further cleaning of "wet parchment." | 10. Hand grading |

illustrated in figure 43. In this case the day after the ripe fruit has been gathered or even that very evening, it is put into a machine which rubs the pulp from the horny stone. The latter, now popularly termed "wet parchment," is then placed in a vat for twelve to twenty-four hours to ferment, thereby removing any of the slimy flesh remaining. After washing, it is drained and spread out to dry in the open. It is raked over three or four times per day to expose the coffee evenly to the sun until uniformly dry. This must be continued for four days to two weeks, depending on the weather. Some concerns, however, use a mechanical drier which accomplishes the same result in a single day. The stones, now known as "dry parchment," are placed in bags weighing 60 to 90 pounds each and sold to one of the local coffee mills. For example in 1927, such parchment was sold at the rate of 16 to 18 cents per pound, and two to three years later at 9 to 12 cents. After the "dry parchment" has been cleaned, it is passed through a hulling machine which removes the horny covering and part of the true seed-coat, or "silver skin". The latter is later partially removed by a polishing machine. The remaining naked seeds, or "green coffee," are thereafter separated mechanically into seven to nine different grades. The better grades are then further inspected usually by women and children who remove by hand all foreign material and defective seeds that may have remained. Thus about 550 pounds of coffee fruits will produce 138 pounds of "parchment coffee," 117 pounds of "green coffee" and, after proper roasting, when the last remnant of "silver skin" is removed, about 100 pounds of roasted coffee "beans." *

BLACK-FRUITED COPROSMA OR LEPONENE

The black-fruited coprosma (Plate 82) is known botanically as *Coprosma crnoides* A. Gray, while by the Hawaiians it is known as *kukainene*, *puncne* or, preferably, *leponene*. Like so many other native plants, it belongs to the *Rubiaceae* or Coffee Family. It grows only on Kauai, Maui and Hawaii at higher elevations. It is particularly abundant in the craters of Haleakala and Kilauea, where its long branches may be observed trailing over the barren lava and volcanic ash. Although more than a score of different kinds of coprosma grow in the Hawaiian Islands, this one can be easily differentiated from the others by having black instead of reddish-orange, berry-like fruits.

* Description of commercial processes adapted largely from mss., of Y. B. Goto and E. K. Nishimura.

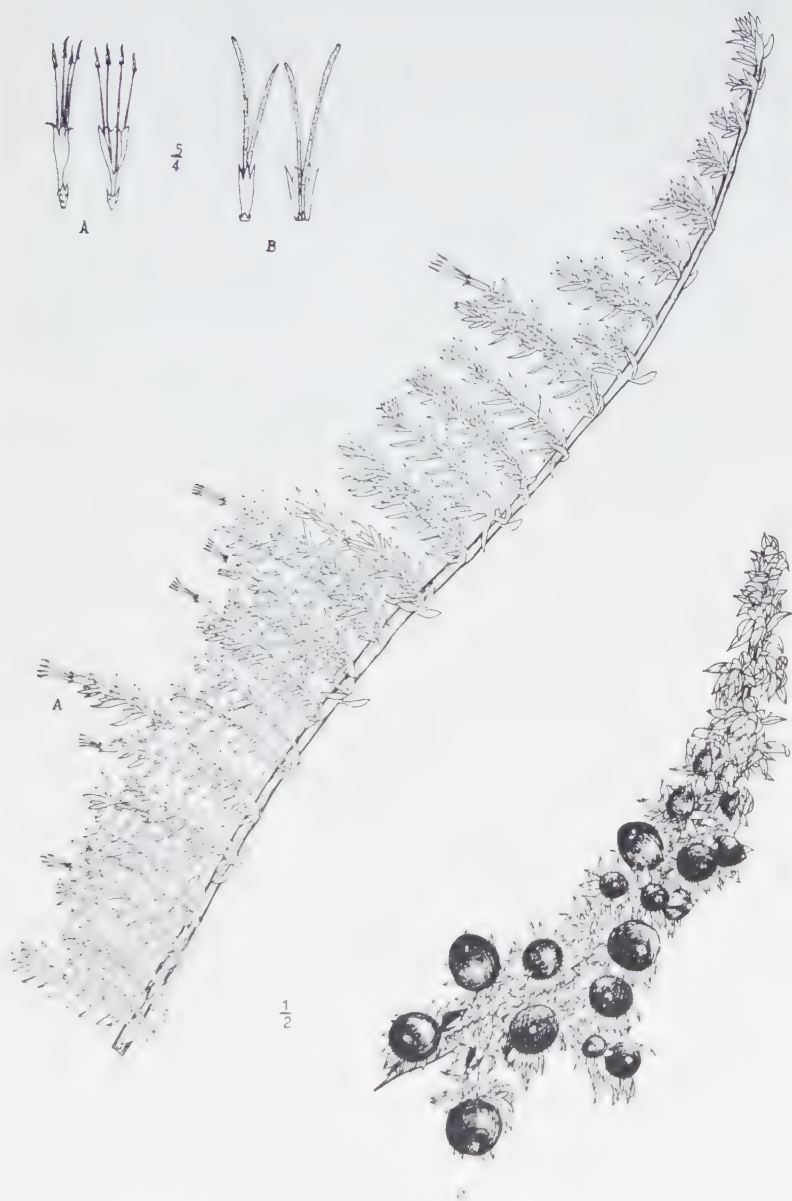


PLATE 82. Black-Fruited Coprosma or Leponene. (Original).

During the early summer, one can notice that the coprosma plants are of two sexes. Some are distinctly "male," or staminate, plants while others are "female," or pistillate. The staminate plant bears inconspicuous flowers stretching four long pollen-filled stamens into the air (A). The pistillate bears similar flowers but, instead of stamens, these possess two thread-like stigmas (B). If pollen grains blown by the wind should become stuck to a stigma, each cracks open to emit a microscopic thread called the pollen tube. This elongates and thus actually bores its way down through the stigma toward the base, called the ovary, where two ovules are located. The first two pollen tubes to reach the ovules then effect fertilization, without which act no seeds could mature. By late summer the fertilized ovules have developed into seeds, while the ovary surrounding them has grown into a black, fleshy fruit (C). By being palatable to birds and swallowed by them, the flesh containing the two indigestible seeds aids in disseminating the plant.

The fruits of the coprosma are greedily eaten by the *nene*, the strange Hawaiian mountain goose (*Nesochen sandwicensis* Vig.) that usually inhabits deserts rather than marshes. Though these birds were quite numerous until a few generations ago in the Kilauea Section of the Park and elsewhere, they were lately on the verge of extinction. With the wise protective measures recently enacted, they are increasing in numbers and may again become one of the more common kinds of wild birds in the Park, continuing to distribute coprosma seeds from region to region as in the past.

To the Hawaiians the plant was of little value. At times its berries were eaten as a laxative.

NONI

The *noni* (Plate 83), *Morinda citrifolia* L., is a member of the *Rubiaceae*, or Coffee Family. This plant has an exceedingly wide distribution, being found in the lowlands throughout warmer regions of the Pacific. In the Hawaiian Islands it now grows chiefly near abandoned native dwellings. For this reason and because of its importance to the Polynesians, some botanists believe that it was purposely brought to these islands by the progenitors of the Hawaiian race during their great migrations.

The *noni* is a small tree very rarely attaining a height of twenty



PLATE 83.—Noni. (Original).

feet. It bears coarse, angular branches and large, shiny leaves. These are borne in pairs excepting where a flower cluster is formed. This consists of a stalk having at its end closely packed flowers in various stages of development. Those near the apex of the cluster are yet green buds, while older buds standing below them are unfolding as small, white flowers ready for the visit of an insect possibly laden with pollen from another *noni* plant. Below these, in turn, stand the remains of former flowers that now consist merely of enlarging, green ovaries. Even before the last flowers in the cluster have bloomed, the older ovaries ripen into small, pale yellow fruits. Because of the close proximity of the flowers in a single cluster and their large number, the small, swelling fruits developing from them finally press against each other with such force that their sides become flattened. Each fruit, instead of being spherical, thus acquires an angular shape. As the entire cluster continues to grow and ripen, the single fruits tend to lose their individuality and unite into one large collective fruit like the pineapple (p. 87) or the breadfruit (p. 126). It (Plate 83, at top) may resemble a potato in size and shape but show on its surface the faint pentagonal or hexagonal outline of each individual ovary. This surrounds the less obliterated circular corolla scar.

The seeds of the *noni* are well adapted for distribution by ocean currents. To each is attached a bladder-like air-sac (Plate 83, at bottom) that gives it buoyancy. It is therefore probable that this shrub owes its great distribution to its flotation mechanism as well as to the Polynesian navigators.

The Hawaiians in the early days ate the foetid fruit of the *noni* in times of famine. It was eaten either raw or preferably cooked to make it less disagreeable in taste. The plant was also used medicinally. The leaves and the bark of the stem were pounded, cooked, and strained. This liquid was then drunk as a tonic. As a reputed remedy against tuberculosis, or *akepau*, the Hawaiian patient drank a medicine called *aumiki awa*, or *apu awa*. This was prepared by taking the fruit of the *noni*, the native black-stemmed sugar cane called *koalele*, and the root of the *awa* (*Piper methysticum* Forst.), pounding and straining each of these ingredients separately and then mixing their juices in a calabash. If a certain blood-red clay, called *koac*, were available, a little of it was added. This was found most abundantly in Kauai. After hot



PLATE 84. Hawaiian Lobelia or Oha. (Original).

stones had been placed in the calabash to boil the medicine, it was ready to use. The overripe fruit of the *noni* was also used as a poultice.

The drink, *aumiki noni*, was prepared from fresh spring water and the juice of the *noni* fruit. This was usually placed near people who were drinking the Polynesian intoxicant *awa* (p. 122) so that they could take some of this to counteract any unpleasant effects.

The juice of the fruit, acting as an insecticide, was on occasion used by the Hawaiians in cleansing the hair. Thereafter they repeatedly passed the dried meat of the coconut against it until it became oily and lustrous. Or, instead, the meat of the coconut was grated or chewed, a little water added, and then smeared on the hair. This shampoo was completed by washing the hair to remove the particles of coconut remaining.

Probably the greatest use of the *noni* was for dyeing *kapa* (p. 137). A red dye, called *pokohukohu*, was made from the bark of the root after boiling with lime derived from coral. A yellow dye, on the other hand, was made from the trunk of the plant.

The chemical nature of the *noni* fruit bears study, particularly as to its possible value in the treatment of diseases of the kidneys.

LOBELIA AND RELATED PLANTS

More than one hundred fifty members of the *Lobeliaceae*, or Lobelia Family, are known to be native to the Hawaiian Islands. Our knowledge of these is due largely to the labors of the famous botanist and explorer, J. F. Rock. Every one of these plants is peculiar to the Islands, and by far the greater number belong to botanical groups not represented elsewhere. Though many different kinds of lobelia may be found in Hawaii National Park, few visitors will see any excepting possibly the blue-flowered *Lobelia neriiifolia* A. Gray, which grows on the inner walls of Haleakala Crater and elsewhere, and the greenish-flowered *Clermontia hawaiiensis* (Hilleb.) Rock (Plate 85), which grows in the Kipuka Puauulu not far from Kilauea. The former plant is closely related to a specimen, shown on Plate 84, which was collected on West Maui.

In spite of their rather soft, fleshy stems, most of the lobelia in the Hawaiian Islands are shrubs with candelabra-like branches,



PLATE 85. Hawaiian Clermontia or Oha Kepau. (Original).

or striking palm-like trees becoming usually five to fifteen feet high. They are at their best in the rain forest and on fog-swept cliffs. One plant, *Brighamia insignis* A. Gray, found almost exclusively along the precipitous coast of windward Molokai, resembles an upright, naked pole with a cabbage at its end from the center of which long, white, fragrant flowers arise. All these plants contain a sticky, milky juice and bear rather large, coarse leaves. The flowers are peculiarly curved, bear five petals, and are usually fleshy. These petals are more or less united from their bases into a partial tube that is typically deeply slit on the upper side. In this and in other features, the *Lobeliaceae* resemble the *Goodeniaceae* (p. 292), to which they undoubtedly gave rise.

The curved flowers of the Hawaiian lobelia secrete a quantity of nectar at the base as a means of inducing certain birds and flying insects to visit them, to become dusted with sticky pollen and unconsciously to transfer it to some other flower of the same kind. By such cross-pollination the plants are enabled to mature vigorous seed. Because the flowers of the lobelia are curved, birds with a straight bill would be unable to probe them effectively for food. These islands, however, were inhabited, at least until recent times, by thirty-five kinds of strange, nectar-feeding birds belonging to the endemic *Drepanididae*, or Honey Sucker Family, of which the famous *mamo* (Fig. 44) and *iʻiwi*, and the common *apapane* are representatives. Many of these birds possess beaks having a curve similar to that of the lobelia flowers in the base of which they find their food of nectar and secreted insects. Because both the honey suckers and the lobelia are distinctly Hawaiian and have inhabited these islands for an incredibly long time, as their numerous specialized groups indicate, it is virtually certain that the curve in the bill of some of these birds was evolved to fit the curve of the flower. This is an unusual illustration of interdependence of birds and flowers. Moreover, so that these birds can also suck the nectar from flowers having a different curve from that of most lobelia, the outer third or fourth of the long upper bill of most of these is flexible, not unlike rubber.

The lobelia, usually called *oha* or *ohawai* in Hawaiian, were not of much value to the natives. The leaves of certain kinds (*Cyanca*) were cooked like cabbage, while the orange fruit of others (*Clermontia*) were eaten raw. *Brighamia*, called by various natives *puaala*, *alula* and *ohaha*, was eaten raw as a supposed

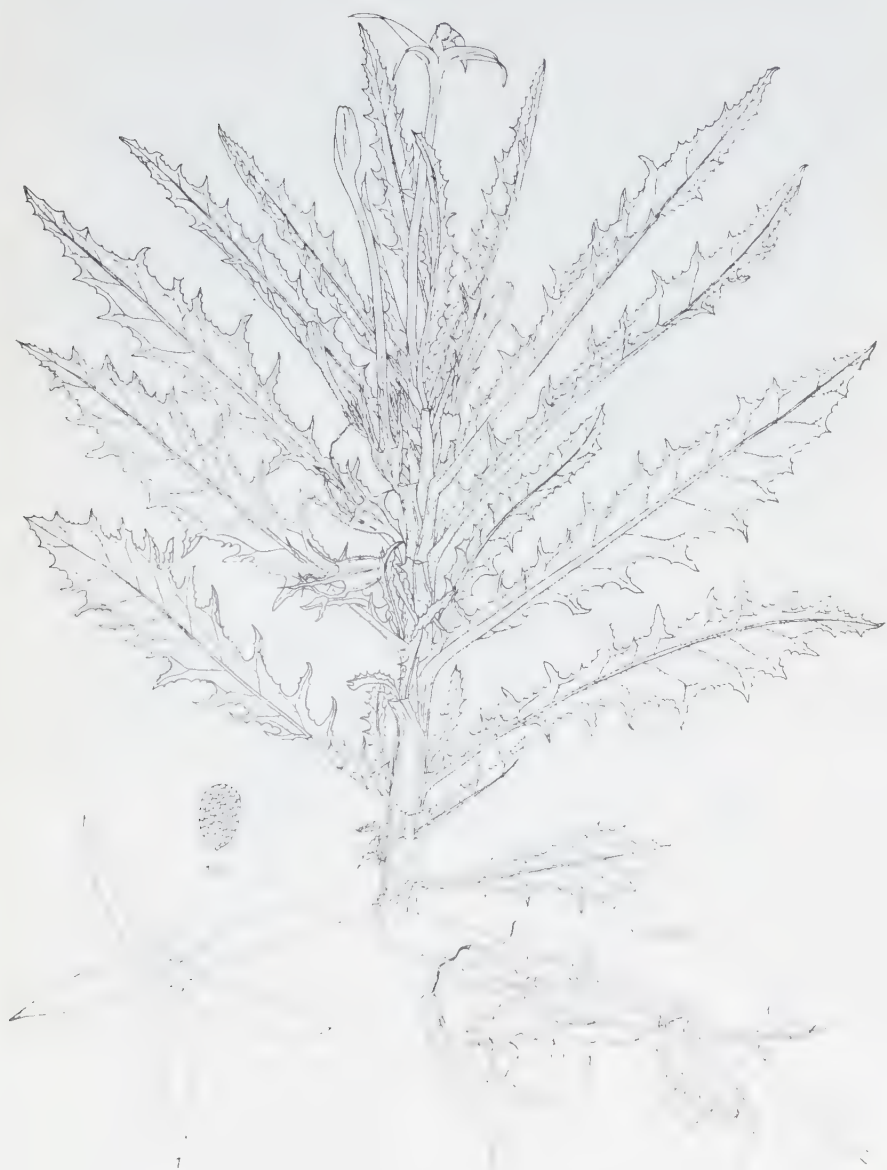


PLATE 86.—Star-of-Bethlehem. (Original).

remedy for consumption and various other diseases. Certain kinds, such as *Clermontia hawaiiensis* mentioned above, were called *oha kepau* because their sticky juice was a favorite bird-lime with the native fowlers (p. 129). The crushed berry at



(Wilson and Evans)

FIGURE 44.—The *mamo*, a nectar-feeder with curved bill.

the same time furnished suitable bait. The juices of entirely different plants were likewise employed in this way as, for example, that of the breadfruit (p. 129). After the birds had been deprived of their choicest feathers, they were often washed free of the entangling juice with the oil of the *kukui* (p. 193) nut kernel before being liberated.



PLATE 87.—Chamisso's Scaevola or Naupaka. (Original).

One lobelia (Plate 86), introduced from the West Indies, is mentioned here because it grows along the roadside between Hilo and the Kilauea Section of the Park. It is locally known as the Star-of-Bethlehem and botanically as *Isotoma longiflora* Presl. It is an herb rarely growing more than two feet high. It bears white, erect flowers that resemble those of the native *Brighamia*. This introduced plant, which now also grows wild on Kauai, should be eradicated, as it is one of the most poisonous plants known. A drop of its milky juice accidentally coming in contact with the eye of a person or an animal may cause blindness.

SCAEVOLA OR NAUPAKA

About a dozen kinds of scaevola, called *naupaka* in Hawaiian, may be found in the Hawaiian Islands. All, with possibly the exception of one growing near the shore, are peculiar to these islands. They are members of the *Goodeniaceae* or Goodenia Family.

The various native scaevola thrive from the arid dunes, within reach of the waves in stormy seasons, to the clearings in some of the wettest rain forests at considerable elevations. All are shrubs or rarely small trees. Unlike their relatives, the lobelia, they lack milky juice. They bear simple leaves and white, or rarely blue or yellowish, flowers. These, like the flowers of the lobelia, are slit on their upper sides. In scaevola, however, the slit is so prominent that it appears as though the upper side of each flower had been torn away.

The somewhat spherical fruit of the scaevola, like that of the cherry, is technically a drupe. It consists of two to four seeds which are enclosed with a hard, woody covering or "stone." This, in turn, is invested by white or black flesh. This group of plants is thus well supplied with means for dissemination. If the juicy drupes of certain scaevola are swallowed whole by birds or other animals for their flesh, the stones protect the enclosed seeds from the digestive juices of the alimentary tract. They are therefore enabled to grow when voided, sometimes many miles from the parent plant. The flesh in other kinds contains corky tissues enabling the seeds to be carried long distances by ocean currents. In still others, the fruits are made buoyant by the displacement of half the seeds by air cavities.

Chamisso's scaevola or *naupaka* (Plate 87), *Scaevola Chamis-*



PLANT 88 - Kilanga Scaevola cf. Nampaka (Original).

soniana Gaud. is found in the open forest in both the Kilauea and Haleakala Sections of the Park. It is a shrub or tree three to eight feet high bearing white flowers partly tinged with purple, and purplish-black drupes.

The Kilauea *scaevola* or *naupaka* (Plate 88), to be technically described and named *Scaevola kilaueae* in the writer's New Illustrated Flora of the Hawaiian Islands, is known only from the rather dry ash fields southeast of the crater for which it will be called. This is a low shrub rarely attaining a height of two and a half feet. Its leaves are thick, pale, about one and a half inches long and half an inch wide, and sparsely dentate toward their ends. Their surface is entirely smooth except when young, at which time it is covered with a coarse, yellowish bloom. The flowers are borne in clusters of three, are dull yellow and have their corolla lobes prominently winged as in most *scaevola*. The drupe is black. It contains a stone surrounding two seed cavities. In about half the drupes examined both cavities contained good seed, while in the other half one cavity contained a viable seed and one was empty. The latter cavity apparently represents a flotation mechanism which may have been functional in the drupe of the littoral ancestors of the plant but is no longer of any value in its present habitat.

The beach *scaevola*, *S. frutescens* (Miller) Krause, but locally often called *S. lobelia*, is the plant that is possibly not peculiar to the Islands. It may be found within the boundaries of the Park, growing chiefly along the shore. It has large, fleshy, rounded leaves with smooth margins, and white flowers. Its drupes, in contrast to those of most Hawaiian members of this family, are white. Because of its occurrence along the coast the Hawaiians knew it as *naupaka kahakai*.

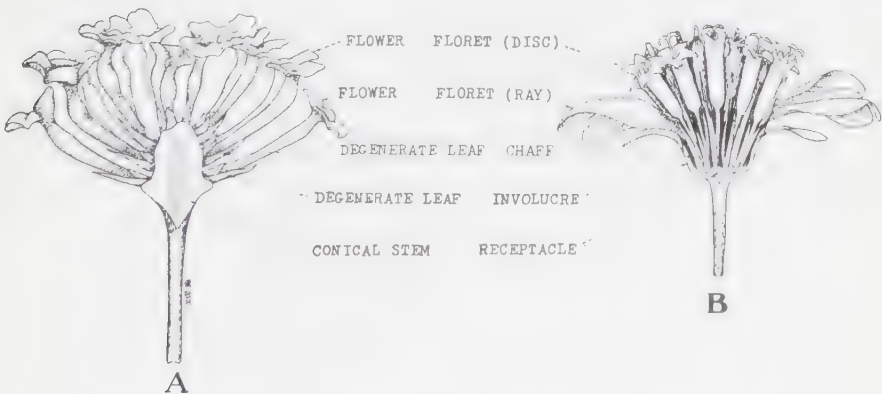
The *scaevola* were of little use to the Hawaiians. The peculiar split of their flowers was naturally noticed by the natives. They found a plausible explanation for this appearance in the story that a maiden called Puna, on accusing her lover of infidelity, tore the originally symmetrical flower in half. She declared in her anger that she would never renew her love until her lover had found a perfect flower. As all have been half-flowers from that time on, he searched frantically but in vain to find the flower that would regain the maiden, and finally died of a broken heart.

BIDENS OR KOKOOLAU

More than sixty kinds of bidens, called *kokoolau* by the Hawaiians, are known from these islands mainly through the researches of E. E. Sherff of the Field Museum in Chicago. These plants grow from the shore to an elevation of 8,000 feet, and from desert-like lava flows to the wettest rain forests. They are members of the *Compositae* or Composite Family, the largest and one of the most highly evolved families of flowering plants existing today.

All *kokoolau* in the Islands, except two introduced kinds mentioned below, are annual or perennial herbs, many of them of considerable beauty. They bear minute flowers that are aggregated into clusters, called "heads" or capitula, which superficially resemble a single flower to such an extent that most visitors to the Park are deceived regarding their true nature. It may not be amiss, therefore, to explain how these structures may have evolved to their present condition. This is best done by comparing the longitudinal section of a hypothetical ancestral flower cluster (Fig. 45, A), such as that of the *lantana* (p. 253), with a diagram of the corresponding structure of a typical *kokoolau* (Fig. 45, B).

The stalk bearing the flower cluster of the *lantana* and that bearing the head of the *kokoolau* are fundamentally alike. At the top of the stalk in the case of the former plant is a conical stem



(Original)

FIGURE 45.—Comparison of flower cluster of *lantana* (A) with flower cluster, called "head" or capitulum, of *kokoolau* (B). Corresponding structures with labels parallel.

bearing closely set leaves and flowers. In the *kokoolau*, on the other hand, this structure, now called the receptacle, differs chiefly by being more flattened so as to become dish-shaped. The outer row of leaves, each of which bears a single flower in the lantana cluster, bears no axillary flowers in the *kokoolau*. These leaves, on the contrary, simulate the green calyx of a typical flower and make up the involucre of the composite head. The numerous flowers of the lantana, each standing in the axil of a leaf, correspond to the numerous small flowers called florets of the *kokoolau*. Even the axillating leaves are present in the latter, though now greatly modified into scale-like chaff. In the introduced *kokoolau* commonly called Spanish needles, which is such a common weed in these islands, all florets may be alike. But in a form of this same plant growing at higher elevations and in the native kinds, the peripheral florets have become modified into petal-like structures. This occurrence of small florets and of petal-like florets in a single head, a condition observed in a vast number of *Compositae*, is the cause of the common error of confusing a complex flower cluster composed of many distinct flowers with one single large flower.

By comparing the two large-scale figures on Plate 89, one notes that the small floret, or disc floret, and the petal-like, or ray, floret are homologous structures each highly specialized for a definite purpose. The one is for seed production; the other, for display to attract insects to the neighboring, inconspicuous disc florets so that cross-pollination may result. Both florets contain an ovary surrounded by the calyx-tube. The ovary of the disc floret contains a single maturing seed, and the calyx bears two tooth-like sepals. These bear downwardly pointing hairs, which, upon the ripening of the ovary into a one-seeded fruit, catch in the fur of animals and thus enable the seed-like fruit to be carried long distances. The ray floret likewise has an ovary, but it is functionless and never bears a seed. There is, therefore, no advantage in scattering it and, because of the absence of barbed sepals, no special opportunity for doing so. Both florets bear a corolla consisting of five petals which are more or less united from their common base. In the disc florets, these petals are small and inconspicuous. But in the ray florets three or more of them have united and enlarged into a single petal-like structure of considerable length.

The presence in many cases in the ray florets of three or more apical teeth, which are the free ends of as many petals, proves



PLATE 89.—Hawaiian Bidens or Kokoolau. (Original).

their complex origin. In addition to these elements, the disc floret bears five stamens, the upper parts of which consist of pollen-bearing anthers and are united to form a single tube around the upper part of the pistil. This pistil is hairy and, on elongating, brushes the pollen into the open where insects may be dusted with it. After a time, the upper part of the pistil divides into two spreading lobes termed stigmas. These now contain the remaining pollen on their outer, reflexed surface, where it is discarded. The inner and upper side, which is the only surface suitable to enable pollen to fertilize the ovule contained in the ovary for the development of seed, is now exposed. Since its own pollen has been shed or rolled out of the way, the floret cannot be self-pollinated. At the same time, the enlarged stigmatic surface increases the chance of being cross-pollinated. As inbreeding often results in loss of vigor in the offspring, this pollination mechanism is of particular value to the plant.

Two introduced kinds of *kokoolau* are known from Hawaii National Park. *Bidens pilosa* L., locally called Spanish needle, is an introduced weed native to tropical America. It was first collected in the Islands as early as 1864 by the late Dr. Brigham, long director of the Bishop Museum and one of the early botanical collectors in Hawaii. This plant is now the commonest *kokoolau* in the Islands and the most troublesome because of its two- or three-pronged fruits that become attached to the clothes of people and the fur of animals. It is extremely common at lower elevations in dry as well as moist, sunny localities. The plant is usually one to three feet high, bearing, when fully developed, compound leaves consisting each of three leaflets. Its heads usually lack petaloid florets, though at higher elevations, as for example in the vicinity of Kilauea, these are present. They are creamy white in color.

A second introduced *kokoolau*, *B. cynapiifolia* H. B. K., is native to the West Indies and Central America. It is evidently of rather recent introduction as it has not been reported from these islands before and, at the time of this writing, is known only on the Island of Hawaii. It may be found within the boundary of the Park on the arid plains south of Kilauea as well as in similar localities as far north as Kealahakua Bay. This plant is characterized by having dissected leaves and small, yellow ray florets in its head. Its

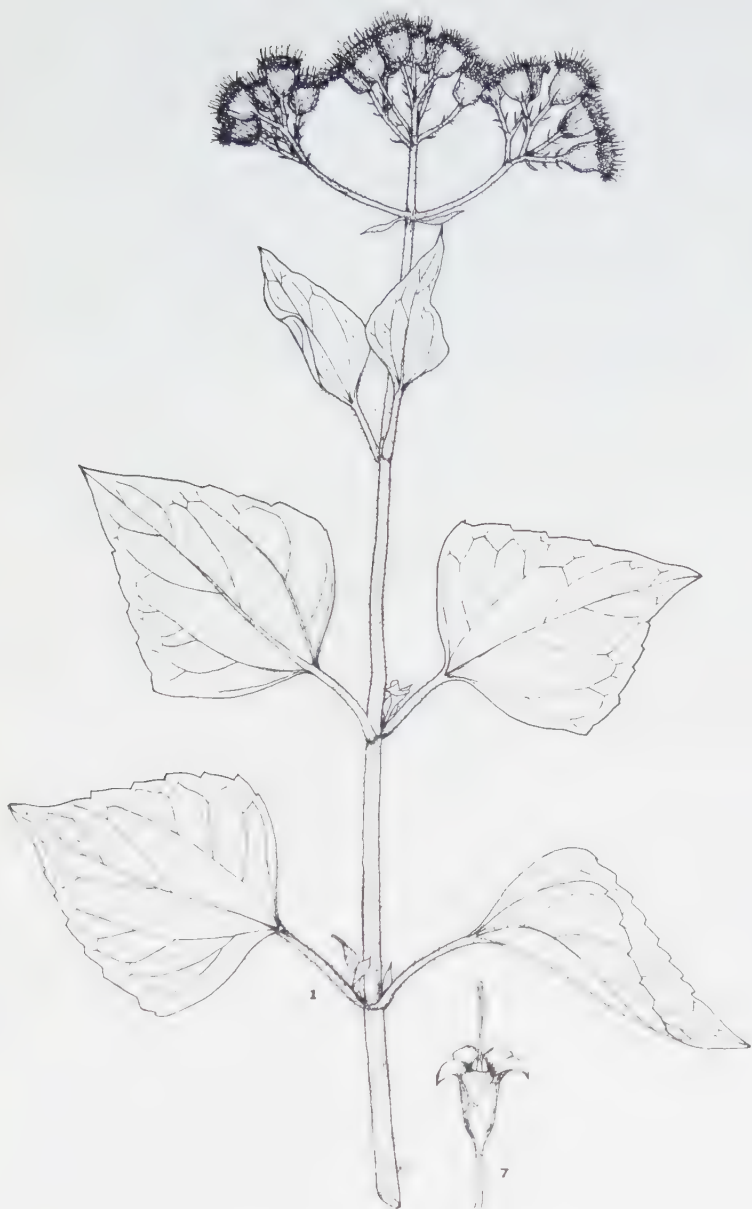


PLATE 90.—*Eupatorium*. (Original).

fruit is long and surmounted by three spreading, barbed teeth. In dry regions, this weed bids fair to become as common as *B. pilosa*.

The third *kokoolau* growing within the Kilauea Section of the Park is the native *B. hawaiiensis* A. Gray. This plant may be seen growing near the Kipuka Puaula, while a slightly different specimen (Plate 89) was found in the first crater south of Kilauea-Iki along the Chain-of-Craters Road. It is no doubt after this type of plant that one of these craters was named Kokoolau by the Hawaiians. Just beyond the boundary of the Park, in the District of Puna, yet another related plant, *B. hawaiiensis* var. *conglutinata* Degener & Sherff, may be seen. This was first discovered by Antone Borges as recently as 1929. All these plants are perennial herbs bearing ovate leaves and showy heads containing yellow, petalloid ray florets.

The fourth *kokoolau* found in the Park is known only from the Koolau Gap of Haleakala Crater, Island of Maui, where it was discovered by the writer and Henry Wiebke in 1927. This plant has been named *B. campylotheca* var. *pentamera* Sherff. It is a tall perennial herb that sprawls over neighboring vegetation to display its large, ornamental, yellowish heads. This plant bears leaves resembling a fern frond that is once or more pinnate.

The native *kokoolau* were greatly valued by the Hawaiians. The leaves were stripped from the plants, dried, and then made into a tea that was considered a tonic or blood purifier.

These plants, like many others, were also a remedy for thrush, a fungous disease formerly common in children. For small infants, the disc florets were gathered, chewed, and then fed to the patient from mouth to mouth. But if the child were more than a year old, the Hawaiians might also employ the leaves, the bark from the stems, and the root.

EUPATORIUM

About the beginning of the twentieth century, a Mexican weed (Plate 90), *Eupatorium glandulosum* H. B. K., became common on the Island of Maui, spreading over the drier slopes of Haleakala and smothering to death the native vegetation standing in its way. It is a relative of the Joe-Pye weed or boneset of the United States, and a member of the *Compositae*, or Composite Family. This pest spread to the Island of Molokai, where by 1925 it had formed troublesome thickets in the valleys of the leeward side. In 1923 only a few plants were found on the Island of Oahu, all



PLATE 91.—*Raillardia* Scabra or Kupaoa. (Original).

growing in one locality, but by 1930 this weed had already established itself in several widely scattered stations. It is obviously spreading over the entire group and will surely speed many kinds of native plants to extinction.

This eupatorium, occasionally called *pamakani* by the Hawaiians, is a woody, upright herb becoming three to five feet high. As in all other *Compositae*, its minute flowers are combined into complex clusters termed heads. These are white in color. Its air-borne seed-like fruits probably enable this plant to spread rapidly from place to place.

Since 1926 a second Mexican eupatorium, *E. riparium* Regel, appeared in the Islands, probably purposely introduced as an ornamental. It was first observed in the vicinity of Hilo, Island of Hawaii. Within four years it has spread along the Hamakua coast as well as along the roadside from Hilo toward the Kilauea Section of the Park. This plant thrives in wetter districts than does the preceding one and therefore threatens to invade the Park, where it will most likely compete with the native plants to their disadvantage. It is considerably smaller than the eupatorium so common on Maui, and has branches that tend to recline. These readily strike root in wet places, in this way producing clumps of plants of considerable extent. It is a great pity that these two eupatoriums have become naturalized. They exemplify the possible danger that occurs when the layman attempts to introduce foreign plants into these islands. He is rarely capable of judging whether his introductions will be ultimately highly beneficial or cause untold damage.

RAILLIARDIA OR KUPAOA

Railliardia, named by Gaudichaud in honor of one of his companions in the exploring expedition under Freycinet in 1819, is the scientific name of a large group of the *Compositae* or Composite Family found exclusively in the Hawaiian Islands. By the natives these were known as *kupaoa*. These plants generally thrive on barren lava flows and on exposed ridges especially at higher elevations. They are herbs or shrubs sometimes reaching a height of twelve feet, and have simple, often leathery leaves. Their heads are yellow to almost white. These are simpler in structure than those of the *kookoolau* (p. 296), bearing but one kind of floret. The fruits of the *Railliardia*, instead of having the per-



PLATE 92.—*Raillardia Laxiflora* or Kupaoa. (Original).

sistent sepals modified into barbed teeth as in most kinds of *kokoolau*, have them modified into a single ring of spreading hairs. These act the part of a parachute to keep the seed-like fruit suspended in the air during windy days. Thus the fruit is enabled to leave the vicinity of the parent plant for some distant locality where the opportunity to germinate and grow to maturity is perhaps more favorable.

In the vicinity of Kilauea two kinds of *Raillardia*, or *kupaoa*, grow. *Raillardia scabra* DC., preferring sunny thickets, is a low decumbent herb (Plate 91) with purplish branches rarely rising higher than two feet. Its leaves are in alternate arrangement and its grayish white heads are erect. *Raillardia laxiflora* DC., on the other hand, is a small, erect shrub (Plate 92) most common in the more open localities, especially between the Kilauea Military Camp and Uwekahuna Observatory. Its leaves are typically borne in whorls of three and its yellow heads are drooping. The root of this plant is fragrant and was often used by the Hawaiians to perfume their *kapa* (p. 132) and precious feathers. Within Haleakala Crater, as well as on its slopes, three or four other *kupaoa* may be found.

The heads of the *kupaoa*, as well as those of the silversword (p. 306) and its relatives, are badly parasitized by peculiar Hawaiian flies. The eggs are laid in the young heads, and hatch out as maggots. The maggots then feed on the developing florets until it is time to pupate in the heads preparatory to developing into flies. These insects are not harmful to the parent plant, but by feeding on the florets, greatly reduce its ability to perfect seed.

EUROPEAN WOOD GROUNDSEL

Within recent years the European wood groundsel (Plate 93), *Senecio sylvaticus* L., has gained entrance to these islands where it finds conditions favorable for growth at higher elevations. It is rather common in central Molokai in clearings, and extremely abundant on Maui within Haleakala Crater, just below the Rest House, but quite rare in the Kilauea Section of the Park.

It is a member of the *Compositae* or Composite Family and bears its small, bright yellow flowers, or florets, in heads. All appear alike at first glance, but with a lens one can see that those in the outer peripheral row are petaloid in structure. As in the



PLATE 93.—European Wood Groundsel. (Original).

Railliardia (p. 302), the fruits are tufted with hair to enable the plant to be disseminated by the wind.

SILVERSWORD AND GREENSWORD

Probably the most striking Hawaiian plants are those belonging to *Argyroxiphium*, a group classified as members of the *Compositae* or Composite Family. These plants are exclusively Hawaiian.

Contrary to popular belief, there are five distinct kinds of *Argyroxiphium*. The best known is the famous Haleakala silversword, *A. macrocephalum* A. Gray. To the Hawaiians it is known as *pohinahina* or *ahinahina*, merely variants for their word for gray.

The Haleakala silversword, when young, is a beautiful silvery sphere of incurved, linear leaves. The plant owes its color to a dense covering of hair which, as with the native geranium (p. 187), repels some of the penetrating rays of the sun. This protection seems desirable, as sunlight is more intense at high elevations than at low. The hair also guards the plant from too rapid loss of moisture by evaporation through its leaves.

When the plant has attained a diameter of about two feet, it shoots up a magnificent cluster of flowering heads to a height of three to six feet. In that stage it resembles the illustration on the cover. This flowering stalk bears sticky, glandular hairs, as does the silene (p. 154), to prevent crawling insects from reaching the flowers for pollen and nectar, the plant thereby reserving these two foods exclusively for flying insects. The flowering heads themselves are not particularly beautiful, bearing small yellowish disk florets and about twenty-five purplish ray florets.

After maturing their seed-like fruit, of which many thousand are normally produced, the silversword dies, just as the century plant does after it has seeded. This is probably because the flowering stalk terminates the growing tip of the plant, and no side shoots develop to continue growth. Of all the silverswords studied during three weeks' botanizing within the crater, the writer saw only one plant that had produced a secondary branch. This arose about an inch above the top of the root.

The Haleakala silversword was very common within the crater and on its rim until the beginning of this century. According to reliable accounts, the plants were so abundant in the latter half

of the nineteenth century as to make "the hillside look like winter or moonlight." Where a garden of silverswords ten acres in extent was growing in the '90s, not one plant could be found in 1927. Silverswords were so common on the cinder cones in the early days that tourists were accustomed to uproot the largest specimens, merely to watch them roll down the slopes like giant snowballs. As late as about 1915, these plants were ruthlessly gathered in great numbers and dried to be shipped to the Orient as ornaments. In 1927 considerable hunting for this plant within the crater disclosed barely a hundred specimens.

From its former abundance and its present scarcity, the Haleakala silversword appears to be on the road to extinction unless action is taken. Two main factors are responsible, namely man and insects. Dangers to the plant due to thoughtlessness and sheer vandalism by man have already been mentioned. This is now being reduced to a minimum by education and, in the very few necessary cases, by fines. Danger to the plants from insects is more complex. At least six kinds of insects, many of them new to science, are more or less injurious to the plants. A leaf-hopper (*Ilburnia argyropyphii* Kirk.), for example, is sometimes found in great numbers sucking the sap from the silversword. This insect, fortunately, is partly controlled by a wasp (*Polynema* sp.) so small as to be barely visible. This presumably searches for the eggs of the leaf-hopper, into each one of which it lays a single microscopic egg of its own. The latter hatches into a larva that feeds on the contents of the leaf-hopper egg and then pupates. Instead of a leaf-hopper emerging from the shell, an adult wasp crawls forth.

An undescribed phycitid moth and a gray fly (*Tephritis cratericola* Grimshaw) are the two kinds of insects that prevent the silversword from increasing in number. The caterpillars of the moth begin to feed in the centers of the very young flowering heads. Then when these are ready to open, hardly a floret remains to produce seed. The fly causes as much if not more damage than the moth. Its yellow maggots feed on the florets and pupate among their remains. In 1927, because of the ravages of these two insects, the loss of seed was so enormous that only a few could be gathered for propagation. Only in exceptional cases will young plants grow to take the place of the old, since the plants always die after flowering and few seeds escape destruction.

The most practicable way to increase the number of silver-

swords in Haleakala is to spray the plants judiciously with insecticides from the time the flowering cluster develops until the seeds are mature. This work should be supplemented by placing fine-meshed cages over a few clumps of sprayed plants just before these are ready to reproduce, and insuring cross-pollination at the correct time later on. This would enable the ripening of many thousands of good seed. These could be scattered or raked into the cinders in favorable places for growth.

The Hawaii silversword is known as *A. sandwicense* DC. It is limited to the Island of Hawaii, thriving on the barren stretches of Mauna Loa, Mauna Kea and Hualalai above an elevation of 7,000 feet. This plant closely resembles the one on Haleakala. The upper part of its flowering cluster is shown on Plate 94. The plant was probably first collected by David Douglas who had been sent by the Royal Horticultural Society of England to gather interesting plants in the New World. The Douglas fir was one of his finds and named after him. There is little doubt but that, while collecting on the slopes of Mauna Kea in 1834, he was purposely pushed by a former convict into a pitfall containing a wild bull. Douglas was gored to death and now lies buried in historical Kawaiahao churchyard, Honolulu.

Mount Eke is the well-preserved core of an extinct volcanic cone north of Iao Valley, in the western part of the Island of Maui. Due to its elevation of almost 4,500 feet and the topography of the surrounding country, this mountain is covered with clouds most of the time. Only on rare occasions is its summit exposed to the direct rays of the sun and that almost always in the early morning. This summit is essentially a circular plateau about half a mile in diameter, covered with an impervious clay. Here and there are shallow pools of water fed by the heavy rains and mists, and, in a few depressions, seemingly bottomless pits with slippery sides of clay. The entire plateau has no trees and is covered almost entirely by low sedges as with a lawn. Among these, curious silverswords grow in such profusion that, in spite of the disinclination to do so, it was often necessary for the writer to step on the plants to get from one place to another. To see such a field of silverswords was the more startling, as none can be found below the summit.

This Eke silversword, named *Argyroxiphium caligini* Forbes, is characterized by dividing and creeping profusely over the



PLATE 94.—Hawaii Silversword. (Adapted from W. J. Hooker).

ground and progressively dying back at the base, thus isolating the branches into independent plants. It does not produce silvery spheres two or more feet through, as does the Haleakala plant. Instead, its mass of leaves is rarely six inches across. Of the many thousand plants growing, all of which could be easily seen, only one showed the remains of a flowering stalk in the late summer of 1927. This was about two feet high. Besides growing on Mt. Eke, this plant may be found in small numbers on Puu Kukui, a higher mountain located across a deep ravine to the south.

Before discussing a second kind of *Argyroxiphium* on Mt. Eke, it is best to consider another Haleakala plant. In the Koolau Gap of that region the rainfall is considerable, as it is the lowest spot through which the trade wind can blow into the bowl of the crater. Here a rare counterpart of the silversword may be found. This plant is exposed neither to such extremely dry conditions nor to such intense sunlight as the silversword that grows on the cinder cones barely three miles away. It therefore requires a sparser covering of hair and can have broader leaves for exposure to the sun. The plant, consequently, has a greenish tinge and a less compact appearance. Because of its color it is best known as the Haleakala greensword (Plate 95) or, botanically, as *Argyroxiphium virescens* Hilleb. Like the silversword, these plants are magnificent spectacles deserving effective protection from man and insects.

The greenswords observed become taller than the silverswords at flowering time. The area in which they grow is just beyond the present boundary of the Haleakala Section of the Park. Here also may be found the rare geranium relatives and the sandalwood trees previously described. Though only one silversword was observed to branch while in the vegetative stage, of about thirty greenswords seen, several had each produced a second branch. In one plant, the older branch had flowered, seeded and died, while the younger was still growing vigorously. This latter, no doubt, would produce its own flowering cluster later on.

On the northern side of the summit of Mt. Eke and on Puu Kukui to a lesser extent, a very rare *Argyroxiphium* may be found. This, hitherto, has been considered merely a variety of the Eke silversword because of its similar habit of branching. That is not strictly correct. The plant is a second kind of greensword and hence will later bear the name of *Argyroxiphium Kai*.

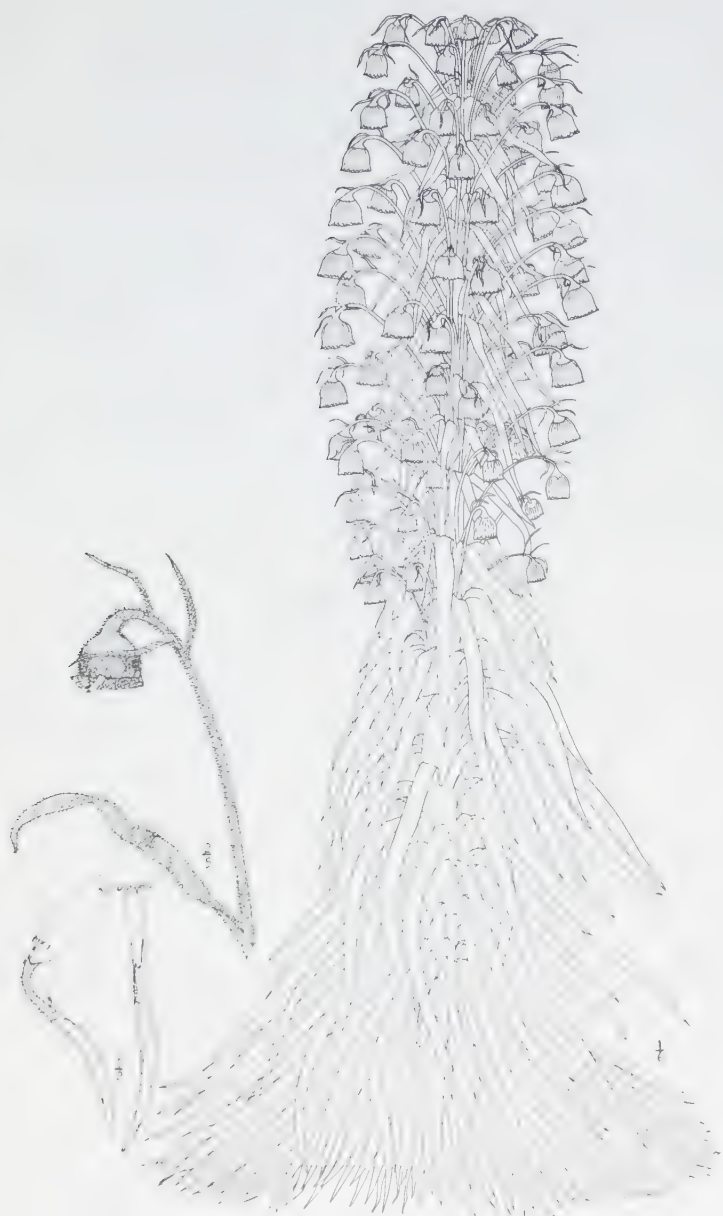


PLATE 95.—Halacala Greensword. (Original).

In studying all the different representatives of the Composite Family found in the world, of which more than 25,000 have already been described, only seventy have heads of an unusual type of construction. Sixty-two of these plants grow from Oregon to Chili, one grows in the Galapagos, while the remaining seven are found only in the Hawaiian Islands. Two of these last are called *Wilkesia* and grow on the Islands of Kauai and Maui; the remaining five are either silver- or greenswords. As the *Wilkesia* and the *Argyroxiphium* are very closely related, one comes to the conclusion that both groups of plants on these islands came from a common ancestor which reached here from the American Continent untold ages ago. From the structure of their heads and from their vegetative features, it is evident that these plants have become highly specialized in order to survive in an unusual and harsh environment. Their characteristics are simple due to the degeneration or reduction of useless or even harmful features, and not due to primitiveness.

The silversword and the greensword, as far as known, were not used by the Hawaiians.

CONCLUSION

The foregoing pages should have drawn attention to the unique character of the Hawaiian Islands, particularly in respect to their flora; should have taught a few fundamental principles of Botany; and should have imparted a feeling of respect for the ancient Hawaiians and their customs, both perhaps recalling Homeric Greece to mind.

For the comprehensive Flora, the writer is collecting additional information on native plants and their relationship to the Hawaiians, as well as on the circumstances and the time of introduction of foreign plants into these islands. Any data to that effect, and the correction of facts in the present text, will be greatly appreciated.

Work has progressed to such an extent that it is not too early to make a preliminary announcement concerning the

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